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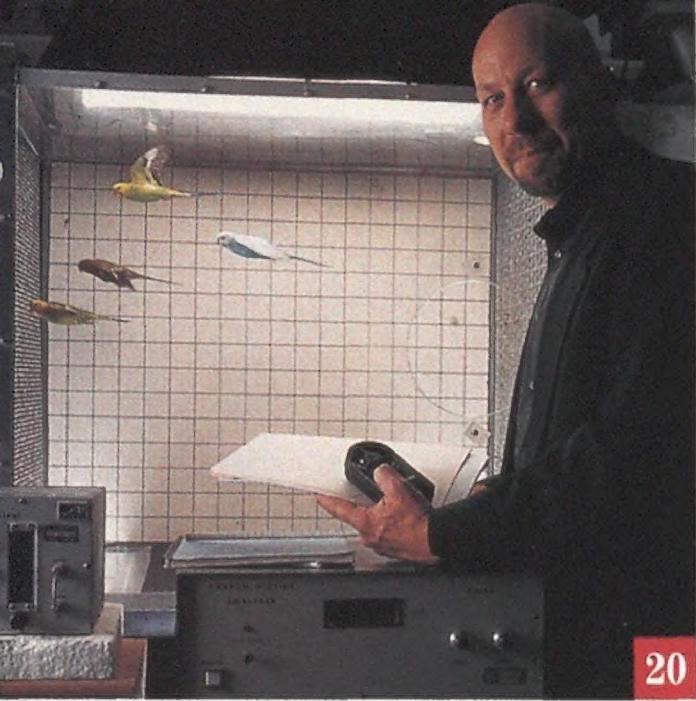
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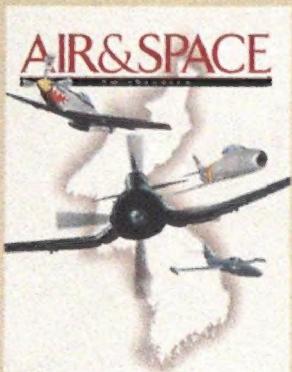
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**Cover:**

"Symbols of the Korean War: F-51, F4U, F-86, F9F" by Matthew Frey of Wood Ronsaville Harlin, Inc., depicts the diverse force that fought in Korea.

AIR&SPACE

Smithsonian

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Korea at Fifty

It's hard to believe that this year marks the 50th anniversary of the outbreak of hostilities in Korea. When the war started, the United States had the advantage of being able to muster a large pool of personnel who were trained in the aviation field and who had relatively recent combat experience in World War II. They knew how to get things done and, more importantly, how to survive. It is a good thing we were able to call on that experience because our military forces were caught almost completely unprepared. The Korean conflict was a war in which innovation played a key role, especially in aviation, and that's what ultimately allowed our air forces to prevail.

The euphoria that swept the nation after World War II affected the entire nation's perception of our need to sustain capable combat forces in peacetime and led to a debate that has some of the same features as today's dialogue. I always find it interesting when I come across an idea that seems to be contemporary, only to find that it is fifty or a hundred or, in some cases, thousands of years old. It seems we have to learn the same hard lessons over and over, and the troops out on the pointy end of the stick pay the price. That was certainly the case in Korea. It was also the first time U.S. military forces experienced a war that the American public not only didn't support but actually resisted, a phenomenon that burst into full bloom during the Vietnam War. Despite that change on the home front, in Korea the troops on the pointy end were superb.

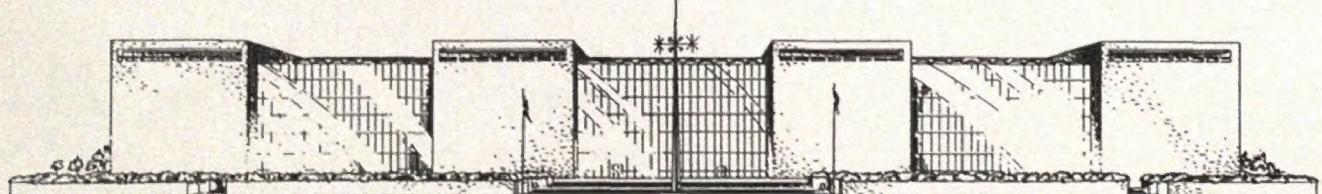
What does this have to do with our principal role as a museum? A lot. Our mission here is to preserve the heritage of aviation and space. Take a tour through the World War I, World War II, and Sea-Air Operations galleries and you will find

aircraft and other artifacts that made a difference in the outcome of battles. Often the equipment was not ideally suited to the task—the first jets in Korea (see "The Forgotten Fighter," p. 36) being just one example—but the people who were responsible for getting the job done made the necessary adjustments and worked around the deficiencies. This is an area where I think we at the Museum do a pretty good job of illuminating history. It is important for our visitors to understand the skill and courage that were associated with success gained through the innovative employment of air- and spacecraft, and examples of such human ingenuity span the spectrum of flight.

NASA's recent experiences on Mars are good lessons on the risks associated with innovation. The agency is being criticized for recent failures, and it is true that some of the project teams made basic mistakes. The important point that critics overlook is that if NASA didn't experience failures, it would mean that the agency is probably not exploring the leading edge of technology, as its charter charges it to do. NASA is responsible for doing the hard stuff, the things that are too risky for industry to try. When the projects are successful, they lead to giant leaps in technological progress.

The artifacts we display at the Museum are tributes to this country's leadership role in technological development over the past hundred years. We focus on the "firsts" or the "bests," not the routine. That is also what NASA and other agencies charged with research must do, and we will save room in the museum for future examples of the fruits of their labors and American ingenuity at the cutting edge.

—J. R. Dailey is the director of the National Air and Space Museum.



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LETTERS

Gooney Bird, Toasted and Roasted

After going through the Douglas factory course during World War II, I was assigned to a DC-3 crew that was training in formation flying, parachute supply missions, and glider towing ("High Mileage," Apr./May 2000). Upon arriving in England as the new man in the squadron, I got the oldest plane they had. It had been a civilian airliner that the Army bought and retrofitted with new radio and navigation equipment. The first thing I did was read the maintenance records to see what I had. Much to my surprise the former DC-3 had 80,000 hours on it. But it still flew like a new plane.

—Leslie E. Veit
Levittown, Pennsylvania

I started working as a rigger for a major airline in the spring of 1951, with a fresh airframe-and-engine license in my pocket. The aircraft I worked on were DC-3s, -4s, and Boeing B-377s, the Stratocruisers. We removed and installed wings, control surfaces, cables, and anything else that produced lift and directional control. The ailerons on a -3 were a bear to rig since they are each operated by two bell cranks connected to one another by two cables. These had to be tensed so rigging pins would slide in and out of holes easily, and much tweaking was required to achieve proper cable tensions. Torquing the 200 or so wing attach bolts was a tiresome job too. Pegging de-icer boots in place was no fun either. Rigging the hydraulic auto-pilot servos required some patience. It was a good job,

however, and when I hear a -3 go over I still dash out to watch it and listen to the music of the Pratt & Whitney 1830s.

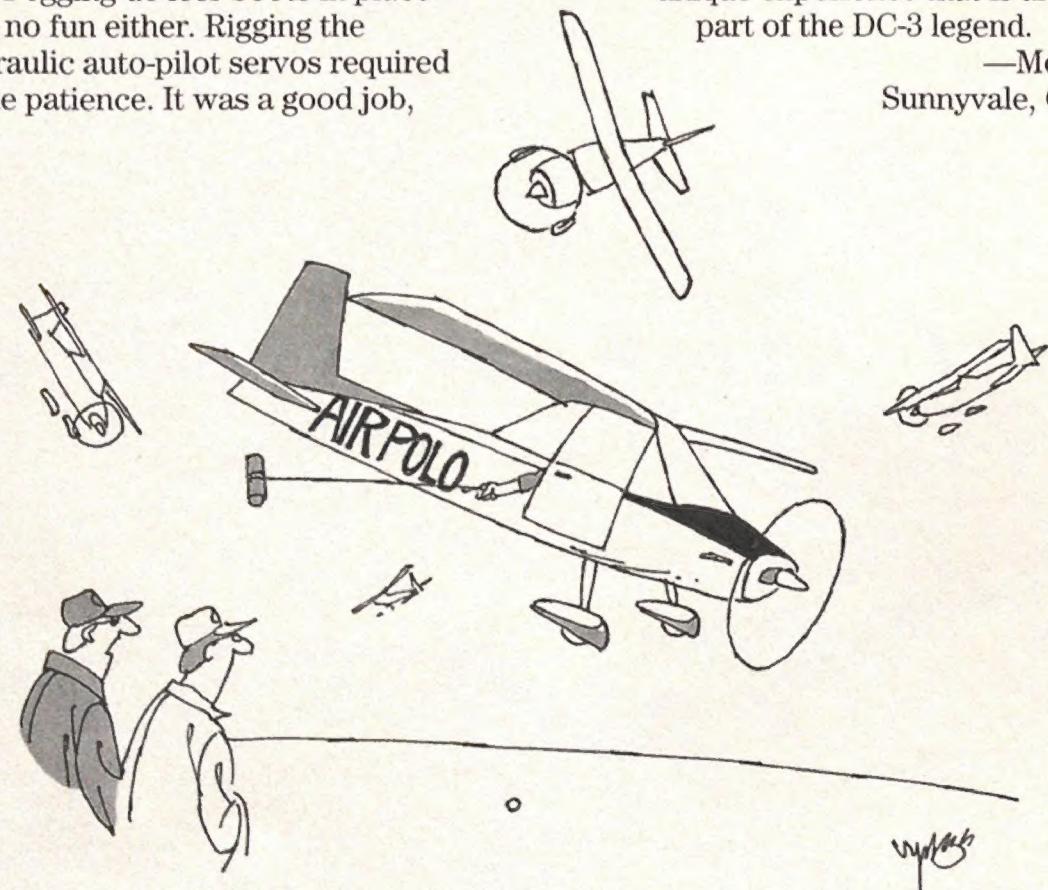
—Bob Lackie
Richfield, Minnesota

I wanted to let you know that there are two old girls still working hard for a living in Anchorage. ERA Aviation, a regional airline, has two beautifully restored DC-3s. We use the aircraft primarily for scenic tours, but when needed, the DC-3s are put on the line to fly the airline schedule. I would imagine that these two aircraft may be the last DC-3's to fly the line in Part 121 Airline Operations.

—Buff Normand
Anchorage, Alaska

Your article left out an important segment of the aviation industry that is still using the -3 quite profitably: skydiving. Noisy and slow as it is, a DC-3 jump ship still has a certain atmosphere that is unmatched in the sport. The 20- to 30-minute climb to altitude allows time for naps, reading the paper, mentally or physically rehearsing the upcoming jump, or just relaxing near the door and checking out the view. Even for non-jumpers, watching DC-3 jumps has a special thrill. The plane is so huge and the wings so massively oversized for the airframe, it always appears to be several thousand feet lower than it is. Watching a stream of dozens of bodies pouring out of the plane in just seconds is truly a unique experience that is an integral part of the DC-3 legend.

—Moshe Preil
Sunnyvale, California



"Think it'll catch on?"

I went to work for Douglas right after graduating from high school in 1935. In spite of all the mythology surrounding the DC-3, the people who operated and flew it did not always consider it a good machine. It was a handful in a thunderstorm and was terrible to land. You had to open the window to see well enough to taxi. The steam heat system was a farce. Mechanics had to put a jug of water in the cockpit. In the air, the copilot removed a plug from the steam line, poured in the water, and screwed in a steam vent valve from his flight kit; then we had heat. If it rained, the cockpit showered. The wing de-icer boots were effective only if you let the ice build up solid and then turned on the boots, hoping the ice would crack off. I can go on forever about this junker. Eastern and American both dumped them immediately after the war. Thank God I lived through it.

—Dale D. Holcomb
Bethpage, New York

Huey and Cry

I am a retired Army crew chief (post-Vietnam era), and "Huey" (Apr./May 2000) brought back many memories of my time with the Huey, including one episode when our cabin heater broke on an extended flight in Alaska—at minus 40 degrees—and we had to fly three hours back to Fort Wainwright. We were so cold and so tired, and the windshield was so iced up, we landed at the wrong hangar. Still, in spite of the cold affecting both the crew and the Huey, the aircraft never let us down during that flight.

—Bob Stout
via the Internet

I thought you did a fine job until you mentioned the word "chopper." I piloted the Huey 895 hours in 10 months. During my tour, we called them helicopters, helos, and even ships, but we never referred to our aircraft as "choppers."

—Gordon S. Hall
Memphis, Tennessee

On page 29 there is an image of a UH-1 helicopter. The aircraft is identified as belonging to the U.S. Marine Corps, but it has an Iron Cross on the right door. Are German pilots flying Hueys in California?

—Walter Wade
Roseville, California

Editors' reply: Photographer Ted Carlson reports that the Huey in

Lost and Found

I was very disappointed to see that the poster ("Vietnam Vets," Apr./May 2000) proclaimed the aircraft depicted to be "significant." By implication, you have relegated the de Havilland C-7 Caribou to the category of insignificant Vietnam War aircraft. As an ex-Bou driver who has slipped the surly and humid bonds of South Vietnam, I feel slighted. Sometimes when I see posters such as this one, I get an empty and hurt feeling in the pit of my stomach—the same sensation I experienced over 20 years ago when, at the end of a 12-hour crew day, sweaty and grimy and riding back to the hooch, I would shake my head and wonder why we were there. I believe I can speak for a whole bunch of us Caribou air crew when I say that we too faithfully did our duty, and that the contributions of the rugged and not-so-glamorous C-7 deserve to be treated with respect.

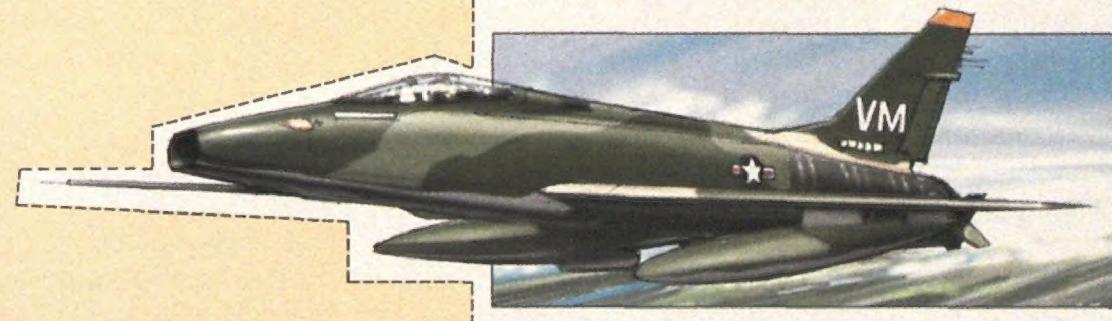
—Lt. Col. Shanon P. Dunlap
U.S. Air Force (ret.)
Madison, Alabama

When I saw that your latest issue included a poster on Vietnam War aircraft, I got excited. However, the excitement didn't last long, because the aircraft I flew in Vietnam wasn't included—the F-100 Super Sabre. During most of the war, the Air Force operated four wings of F-100s, stationed at Bien Hoa, Phan Rang, Tuy Hoa, and Da Nang, if my memory serves me right. On 24 hour-a-day alert, these wings flew significant ground attack missions throughout the length and breadth of South Vietnam, against pre-planned (fragged) targets and against emergency targets, including enemy locations, troops in contact, etc. The F-100 had a long and proud history in the Vietnam War and to see it deemed "insignificant" does not do it or its pilots justice.

—Dennis Cole
via the Internet

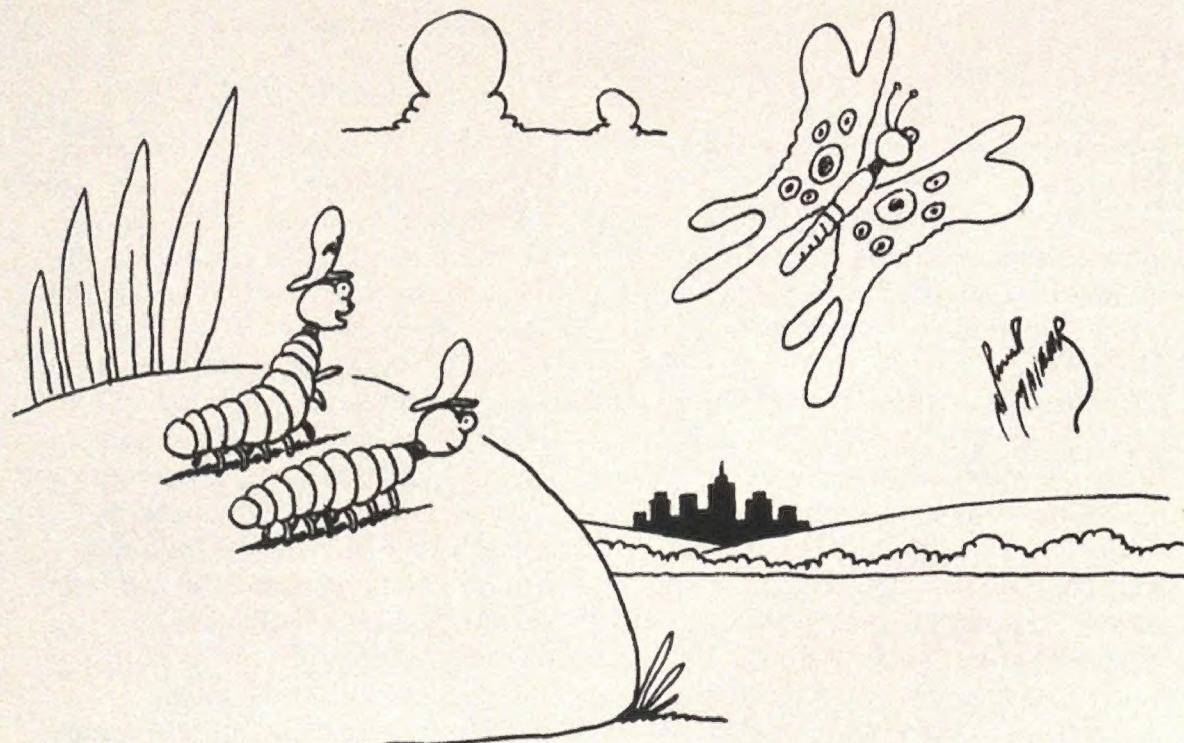
Editors' reply: Our peace offering: illustrations by artist Harry Whitver ready to be clipped and glued to the original poster. Get out those scissors...

North American F-100 Super Sabre



de Havilland C-7 Caribou





"Wow! Imagine the military applications."

question, which belongs to squadron HMLA-169, is adorned with a derivative of a Maltese cross, which was first used as a squadron insignia when the unit was established in 1971. A similar cross forms the basis for the Marine Corps sharpshooter badge, as well as the Navy Cross.

Not THAT Close!

In "Starz in the Hood" (Apr./May 2000), the caption on page 52 mentions that Barnard's Star has a parallax of about 10 arc-seconds a year. I believe you mean that it has a proper motion of 10 arc-seconds per year. According to the formula in the illustration, a 10 arc-second parallax would mean it was only about 0.326 light year from the sun.

—Earl Pursell
via the Internet

If the Radar Van's a-Rockin'

The nomination of the Martin XB-51 bomber ("Ahead of Their Time," Apr./May 2000) reminded me of a fright I got in 1951 when testing an Army Signal Corps 584 Radar set for the Baltimore Signal Depot, which sat across from the Glenn L. Martin Airport. During my test, a B-51 took off on a test flight from the nearby runway. My radar locked on to him, and I was pleased to have a target. I tracked him for about ten miles when suddenly something went wrong. The radar indicated that the B-51 had stopped in mid-air. The altitude was displayed, but no ground speed. I quickly checked everything but could

not figure out the problem. Then, just as quickly, the plane started to move toward me really fast. I realized that the test pilot had made a very tight bank back toward the airport. Since his ground position changed little during the sharp turn, it looked as though he were standing still. When he got back to Martin, he made a high-speed pass right over my van. The large disk antenna moved up and up as he got closer, then turned around so fast to track him in the other direction that the movement caused a severe rocking motion in the van—so bad that it nearly tipped over.

—Frederick G. Herbert
Preston, Connecticut

Foiled Again

On behalf of the crew that has to retrieve and repack the 7,500-square-foot parafoil (Update, Soundings, Apr./May 2000), I'll accept your condolences. In fact, since this thing has nearly 500 suspension lines and weighs almost three-quarters of a ton, we actively solicit all the sympathy we can get. We do need to point out a technical inaccuracy, however. While this is the world's largest functional parafoil (ram-air inflated wing), it is not the world's largest parachute.

—Roy Fox
Aerospace Recovery Services
Belleville, West Virginia

Micronauts

"Microspies" (Apr./May 2000) didn't mention the imaginative potential use of micro air vehicles for extra-planetary

exploration, also further demonstrating that Mr. Reynold's numbers have truly universal application. Terrestrial insects see (or, rather, fly in) the same Reynolds numbers as those at the surface of the Martian atmosphere. Thus, an exploratory Mars aircraft that attempts to fly at 350 mph in the thin Martian atmosphere would be outperformed by multiple MAVs that can fly slowly, hover, land, sample, and return to the lander like a bee.

Since Martian gravity is a third of Earth's, for once the scaling effect works in our favor, and the devices could be up to a meter across, as the intense miniaturization required for use on Earth isn't as critical. Indeed, Robert Michelson is collaborating with Tony Colozza, a NASA Institute of Advanced Concepts fellow, and the Ohio Aerospace Institute to investigate the use of entomopters (biomimetic flying insects) in exploring Mars and other extraterrestrial bodies.

—Franklin E. Porath
Ohio Aerospace Institute
Cleveland, Ohio

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Correction

Apr./May 2000 "Huey": The photograph on page 22 (reprinted above) should have been credited to David Burnett/Contact Press, not Gilles Caron/Contact Press.

Buzzing the Blues

Got the Blues?" (Feb./Mar. 2000) reminded me of a unique encounter that I had with the Blue Angels at Seattle's Seafair Airshow. In the late 1950s, I owned a 1912 Curtiss pusher reproduction that was a popular feature at airshows in the northwest. It didn't do anything spectacular—just flying it by the grandstand with the pilot out there on "the front porch" was a show all by itself.

One year, after one of their Seafair demonstrations, the Navy pilots were transported to the announcer's barge, anchored in front of the grandstand, for an interview. This occurred during one of the civilian parts of the show, and I happened to be flying by in the pusher. I should point out that there are two things about the sound of the pusher that cause people who would ordinarily ignore a light airplane overhead to look up at it. First, a pusher's engine sound is notably different, thanks to the exhaust going through the propeller. Second, because the pusher flies so low, the different sound is heard for a longer time. With a good breeze, the Curtiss could practically hover.

So the sound caused the Navy pilots to look up instead of at the cameras and interviewer. When they saw what an unusual airplane it was—I had taken off from another airport, so this was the first they'd seen me—they kept on looking at it. The alert television crew showed the pilots looking up in the bottom half of the screen and what they were looking at in the top half. After I passed, the interview got back on track.

The story doesn't end there. During one of their later visits, the Blues and the Air Force Thunderbirds—who were wildly competitive with each other—were parked together on the Boeing flight test ramp. One of the Blues' Grumman F11F Tigers had mechanical problems and was brought into the Boeing hangar, where I worked, for maintenance. In looking the Tiger over, I noticed something out of the ordinary—a Thunderbirds decal. When I inquired, the pilot told me that the Air Force fellows had stuck them on the first night they were there, and the Blues did the same the next night, sticking their decals on the Thunderbirds' North American F-100C Super Sabres.

"You have Blue Angels decals?" I asked. "I have a super subsonic airplane that I would love to put one of your decals on." I pulled a small photo of the pusher out of my shirt pocket and handed it to him.

He took one look and burst out, "You're the guy!"

"I'm what guy?" I responded.

"The guy that loused up our TV interview at Seafair!"

(And yes, I did receive some Blue Angels decals after the team got back home to Pensacola.)

—Peter Bowers
Seattle, Washington



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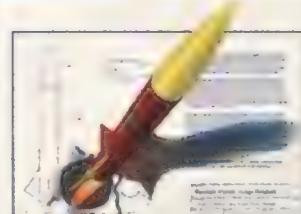
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Rocket Vision

North American's Finest

You didn't need to look at name tags to spot family members among the crowd at the North American Aviation reunion and picnic at Florida's Kissimmee Airport early last April. Actually, you didn't need to look at anything: The sounds of radials and Rolls-Royce engines and turbines spooling up was enough to identify the clan's kin, whose members include the T-6 Texan, T-28 Trojan, B-25 Mitchell, P-51 Mustang, and F-86 Sabre.

Hosted by the Flying Tigers Warbird Restoration Museum, located at the airport, the gathering coincided with the opening of the Experimental Aircraft Association's annual Sun 'n Fun Fly-In in Lakeland, 35 miles west. "Everybody's coming to the south like a pilgrimage to Mecca," said the museum's program coordinator, K.T. Budde-Jones, who organized the reunion, "and I thought, 'Well, they're coming here; why don't we gather ahead of time?' I kept wondering why no one else thought of this, and hoped I wouldn't figure out why when I did it."

The plan was endorsed by Tom Reilly, owner of the museum, who is known for his affection for North American products, having restored nine B-25s, among other aircraft. "It was just a good idea," he said. "Cheap fuel, warm beer, lousy food."

Between its founding in 1928 as a consortium of manufacturers, and its end in 1973, six years after merging with Rockwell, North American Aviation designed aircraft that looked as good as they performed. The company built more aircraft during World War II than any other manufacturer.

"I guess it's just like cars," said Leonard "Stoney" Stonich, owner of an SNJ (the Navy version of a T-6) and president of the North American Trainer Association, when asked about the aircraft's appeal. "Some people like Chevys, others like Fords. But of course ours have a little better history than a Ford or a Chevy."

"I'm a warbird buff, and North



CHRIS SIDELOV

American airplanes just always fascinated me," said Jimmy Rossi, who flew in from Ocala in his F-86. "It amazes me how a relatively new company went out and built airplanes that have never been surpassed. In a period of 10 years, from about '38 to '48, they built five of probably the 10 best in our history." He added with a laugh: "There's something about them. I don't know what it is, but I know it when I see it."

"We all feel like we're family," said Kathy Stonich, Stoney's wife. "It doesn't matter what airplane we have, we all share a passion for these wonderful airplanes that North American built, no matter if they have a round nose or a pointy nose or two engines or whatever. We joke about it, the pointy nose gang and the round engine guys, but it's a pretty good group, all and all."

The night before the barbecue, the museum held a benefit auction of World War II memorabilia in its overstuffed

North American aircraft patrol the skies over Florida at a recent reunion (from top: B-25, P-51, T-28, and SNJ).

hangar. Photographs, uniforms, rare books, posters, and a few airplane parts were spread out on folding tables before a backdrop that included a de Havilland Vampire jet, a Stearman PT-17, and a nitro-burning drag racer. Auctioneer and aviation memorabilia expert Kevin Quinlan detailed the significance of each item: an aircraft spotter book to help civilians identify invading enemy aircraft; pilot's wings stamped "coin silver" on the back, from the war's later years, when metal shortages led the Army Air Forces to melt down silver dollars for its insignia; "trench art," like ashtrays made from spent shell casings.

Bidding was spirited. A set of bound B-24 maintenance manuals went for \$200. T-6 owner Victor Peres bought a magneto for \$100. Don Lockler of



A replica of the Colditz prison glider gets airborne in Hampshire, England, flown by John Lee (left, at cockpit). The original, designed by Colditz inmate Bill Goldfinch (far left) as a last-ditch two-man escape vehicle and built in secret from scrounged wood, salvaged metal, and gingham mattress ticking, was never put to the test.

Tampa, a ground-bound enthusiast who came with his mother and father, a former B-17 pilot, put in the winning \$60 bid on a non-directional beacon antenna dome for a T-6. He plans to make it into a lamp. Tom Reilly paid \$325 for a panel clock from a heavy bomber for the museum's B-17 restoration project. "That big dash clock, they're impossible to find," Quinlan said. "That's a Hamilton 23-jewel movement clock. That piece would cost you double if you went over to Sun 'n Fun and found it at the fly market."

By the time they formed up to fly to Lakeland, almost 60 North American aircraft had alighted at the airport. About 2,500 locals turned out to admire the airplanes. K.T. Budde-Jones and husband Syd Jones explained their own fascination with the warbirds. Formerly commercial salvage divers (they helped treasure hunter Mel Fisher find and recover the *Atocha*, a Spanish man-of-war that sank in 1622), two years ago they took the museum's warbird restoration course and promptly left Key West to work here. Now they own a T-6. "Working on a 17th century Spanish

galleon, you can't put it back together and sail away in it again," said Syd. "You can't talk to Captain Cook or the people from the Spanish Armada, but with these," he said, gesturing at the flightline, "you can not only put them back together and fly them again, but you can actually talk to the original people who operated them. That's the amazing thing."

—James Wynbrandt

Free as a Bird

On a cold, bright morning last February, a group of elderly men watched a glider make its first flight from a field in rural Hampshire in the south of England. Fresh out of the shop, the clunky glider was a replica of one designed and built in secret in Colditz Castle near Leipzig, Germany, during the final months of World War II, as a vehicle for a last-ditch escape attempt. The spectators—all in their 80s—had been British inmates of the prisoner of war camp, which confined habitual escapees to one tightly regulated site where they could be closely watched and from which they could never escape. At

Colditz, guards outnumbered prisoners.

The "Colditz Cock" was the brainchild of Royal Air Force Pilot Officer Bill Goldfinch, who was not a glider pilot, much less a glider designer, and had seen only one glider close up before his incarceration. Designed on a single sheet of paper and built of scrounged bed slats, floorboards, salvaged metal, and jaunty gingham mattress ticking stiffened with boiled millet diverted from meager rations, the glider had been completed and was awaiting launch just before the camp was liberated.

Only one photograph of the aircraft survives, taken by an American soldier who recorded it poised atop a parapet, from where a pair of escapees could have taken off "if the pilot had got control and if we had reached flying speed," said Jack Best, who died in April. Piecing together thousands of components fashioned under the guards' noses, Best and Goldfinch had assembled the glider behind a false wall in a castle attic. Captured in 1941, Best had ended up in Colditz after attempting to tunnel out of three camps and bribing a guard at another for a road map.

The original glider was lost in the melee of the liberation when Germany collapsed. (It had been brought down from the attic workshop and assembled for all to see, including the amazed guards, then returned to the attic.) The replica resembles the original in most details "except that it had proper dope for the wings and proper metal for the skids," said Best, "which we didn't have because we couldn't have cared less what would have happened to the fuselage when we got it down." It was



Space stamps go where no stamp has gone before: Of the 15 Space Achievement and Exploration stamps to be issued in July, the series saluting the exploration of the solar system is the first set of pentagonal stamps issued by the U.S. Postal Service; the view of Earth from the Apollo 17 mission, showing the continents of Africa and Antarctica, is the post office's first circular and first hologram stamp.

built by Southdown Aero Services in Lasham, Hampshire for a British documentary on Colditz and was based on the original sketch, which had been nibbled on by Colditz mice, and a version of Goldfinch's plans that he drew up when the war ended. The wings were subcontracted to John Lee, an aircraft homebuilder and cabinetmaker, who demonstrated his faith in the design by flying it for the film. His verdict: "A very nice aeroplane. The glide ratio is about 18:1, the product of a very clever design."

Tethered to a cable that was fixed to a truck, the replica soared lightly into the morning sun after the briefest of ground runs. After reaching 600 feet and releasing the tow line, Lee slowly brought the glider down, and it touched down on the grass "just like it's kissing the earth," a former Colditz resident remarked. The glider is on display at the Imperial War Museum in London until the end of the year, when it will move to a permanent home at the IWM's Duxford Airfield in Cambridge.

—Stephen Bloomfield

"Everyone Face Their Neighbor—and Line Him up in the Crosshairs"

Who wouldn't want to fly jets with a bunch of fighter jocks, rather than attend another one of those touchy-feely management training programs? Lots of people, if the claims of a company called Afterburner Seminars is any indication.

Formed in 1996 by former Air Force fighter pilots James "Murph" Murphy, George "Gundawg" Dragush, and Anthony "AB" Bourke, Atlanta-based Afterburner Seminars claims that in a single "Afterburner Day," it can train

NASA engineer Steve Hall demonstrates his space station patch kit, which will allow astronauts to repair external damage from space debris.



EMMETT GIVEN/NASA MARSHALL

businessfolk to think and act with the speed and clarity of fighter pilots flying in combat. "When we first meet [the customer at a seminar], we barge in wearing flightsuits, we grab them and tell them they're on a military mission, and take them to an area we've got decorated like a military bunker with parachutes and camo netting, and the theme from *Top Gun*'s playing," Dragush says. "They know right off the bat they've never done this before."

From there the group splits into "squadrons" and learns real fighter pilot stuff, like "the Six Steps to Effective Combat Mission Planning" (from defining objectives to contingency planning), how to "Brief, Execute, Debrief" while eliminating "Task Saturation" (information overload), and when to "Check Six"—a.k.a. CYA. There's even a mock Scud missile attack thrown in for good measure.

"Essentially we do a highly customized program," Dragush says. "We find out the challenges their industry faces, then we talk their lingo and walk their walk. We show the similarities between flying a fighter—like dealing with changing terrain—and tie it in with their changing business terrain."

According to the *New York Times*, corporations spend \$55 billion a year on employee training, and 70 percent rely on outside sources—like Afterburner Seminars—to do the work for them. In four and a half years the staff of Afterburner Seminars has grown from one main pilot-speaker to four, and has taught some 30,000 employees—including personnel from 43 *Fortune* 500 companies—to execute their business mission with the precision of an air strike into enemy territory. "What Air Force, Navy, and Marine pilots survive in a task-saturated environment," Murphy says, "is the same thing that businesses are bombarded with every day."

Clients like Home Depot, IBM, Merck, Johnson & Johnson, Bell South, and Allied Signal are eating it up. "You guys are not cheap," writes Scott Jordan of the Ted Lansing Corporation; "however, you gave us the best value and BANG for our bucks."

—Phil Scott

This Old Space Station

In Touchstone Pictures' *Mission to Mars*, a spacecraft collides with a swarm of meteoroids, one of which punctures the pressurized crew compartment. Astronaut Woody Blake (played by Tim Robbins) has to perform an extravehicular repair job in which

UPDATE



LOCKHEED MARTIN

The ultimate in planes-on-poles, a full-scale model of Lockheed Martin's X-35 entry in the Joint Strike Fighter competition is mounted inverted atop a 98-foot pole for radar cross-section, antenna, and maintenance testing at the company's Helendale Measurement Facility in California. After initial radar cross-section testing, some doors and panels will be intentionally damaged and then repaired so that further testing can determine the impact of defects and the effectiveness of repairs on RCS performance. Boeing is performing similar tests on a model of its X-32 in an anechoic chamber ("The NeXt Generation," Dec. 1999/Jan. 2000). The Pentagon requirements specify a radar return about the size of a golf ball. A fly-off between the two JSF candidates is slated this fall.

some glop is hosed onto the outer skin.

The seemingly goofy glue job is closer than you might guess to a repair system that NASA is testing and plans to deploy on the International Space Station. At Marshall Space Flight Center in Huntsville, Alabama, engineer Steve Hall is developing the tools and techniques to effect repairs that could last up to six months, giving ISS crews plenty of time to perform more durable repairs. The system is called (with apologies to the Muppets) KERMIT, for Kit for External Repair of Module Impacts.

If an object put a one-inch hole in the ISS, Hall says the crew would have only about an hour before pressure dropped to dangerous levels. Crews would first evacuate and depressurize the damaged module, then conduct a spacewalk to clean the area around the puncture and take measurements with the tools Hall is developing. On a second spacewalk, a patch tailored to match the damaged

section would be clamped to the skin through the impact hole using a toggle bolt similar to those homeowners use to install shelves on wallboard. A circular gasket forms a seal between an outer transparent cover disk and the ISS' skin. Finally, an injector forces two components of epoxy plastic into the void between the disk and the skin, where the chemicals mix. In two to seven days, the adhesive cures to form a tough patch.

Some previous sci-fi movies showed punctures being repaired from the inside, using the pressure of the escaping air to press a flexible patch into place over the hole. In reality, the racks and equipment that line the space station interior would make it impossible to place a patch from the inside. In some areas of the ISS, as much as 90 percent of the wall space is inaccessible due to equipment installed on it.

According to Hall, working from the inside is difficult, but it can be done: "If the hole was small—up to about a quarter of an inch in diameter—that would work," he says. "They fly a kit on the shuttle...they can use to seal it from the inside. [The substance is] called vacuum putty, and it's used in the lab to seal small leaks. It's a black messy substance like thin chewing gum and made of a mixture of clay and grease.... If the holes are really tiny—pinhole size—they tend to be self-sealing because dust and small particles eventually drift into the opening and reduce [the leak] to almost nil."

The KERMIt system has already been used aboard NASA's KC-135 aircraft,

which flies parabolic arcs that simulate microgravity, so that technicians can observe how the epoxy ingredients flow and mix. An operational patch kit is slated for delivery in September.

—George C. Larson

Plum Island Airport: Up in the Air

For 360 years there's been a farm just inshore of the barrier dunes of Plum Island, off the northeast coast of Massachusetts. Pilots have been drawn to the flat green field between the Merrimack River and Plum Island Sound since 1910, when Augustus Herring and Starling Burgess tested a biplane on the nearby marshes. Eventually the farm, owned by the Little family, was designated an "emergency field" for the U.S. Postal Service (the remains of an airway beacon are still in place), and in 1938 it became Plum Island Airport.

In 1971, the Littles donated their farm to the Society for the Preservation of New England Antiquities. Pilots in the family viewed the airport as an integral part of the historic property. That same year, Dick and Kathy Hordon took a 30-year lease on Plum Island Airport.

Then came the blizzard of 1978, which covered the airport with ice floes. The state brought in heavy equipment to clear the runway for emergency flights, but in the process wrecked it. When the repair work was scheduled, the Hordons took out a 30-year loan to lengthen the runway to a half-mile, put in lights, and otherwise bring Plum Island Airport up to snuff.

Perhaps understandably, SPNEA has no great affection for lightplane traffic. Last December its board of directors voted not to renew the airport's lease, citing insurance costs and the fear of an aircraft crashing into the Little farmhouse (which is a half-mile from the end of the runway). Now the Hordons were faced with losing their livelihood—while still having eight years to pay on the loan—and pilots with losing a down-home destination.

The locals thought they were losing something too. The airport lies on the outskirts of historic Newburyport, which boasts one of the finest collections of 17th century houses in the United States and has become one of the most prized addresses north of Boston. Newcomers to this neighborhood have proved to be some of the airport's most ardent supporters. On a single day, the *Newburyport Daily News* published 41 letters on the subject, with 37 writers in favor of keeping the airport open. "To me, the airport is a tender thing, wondrous, distinctive, spellbinding, exotic," one woman wrote. "Please don't take it away from us."

Is the closure a done deal? "We anticipate taking up the strip and maintaining the land in its natural condition," says the society's president, Jane Nylander. But by the end of last April, SPNEA was having second thoughts. Its staff agreed to talk to airport supporters, with the directors to render a decision by the end of summer.

—Daniel Ford

UPDATE

Going to the Dogs

The Yugoslav Aeronautical Museum in Belgrade has added an object to its "Exhibits That Fell From the Sky," a display of Operation Allied Force hardware ("Spoils of War," Soundings, Apr./May 2000). The canopy from the U.S. Air Force F-16C (left) brought down in May 1999 in western Serbia when a surface-to-air missile exploded near it had survived in one piece, despite having fallen some 5,000 feet. (The pilot bailed out and was rescued.) The canopy had been retrieved from a wheat field by a villager, who had used it as a doghouse for nearly a year. When media reports of the find reached the museum, the staff set out to retrieve it. "The man was delighted to donate the canopy when he heard about the museum," says Colonel Vojislav Stojanovic, "but it was difficult with the dog. He would not let his house get away."



The Old Master

Among the artists who have recorded the history of flight on canvas, Robert Grant "R.G." Smith is regarded as an American master. His paintings of airplanes, ships, and spacecraft can be found in museums and private collections worldwide. They are displayed in the ready rooms and wardrooms of naval vessels, on the walls of the Pentagon and countless military installations, and in Congressional and corporate offices. Those who know the sky best have a special appreciation for his work. "It is not unusual to see a naval aviator standing before one of his paintings and nodding his head, as if to say, 'That's it, I've been there. It's just like that!'" says Dick Knott, a veteran naval aviator and aviation historian.

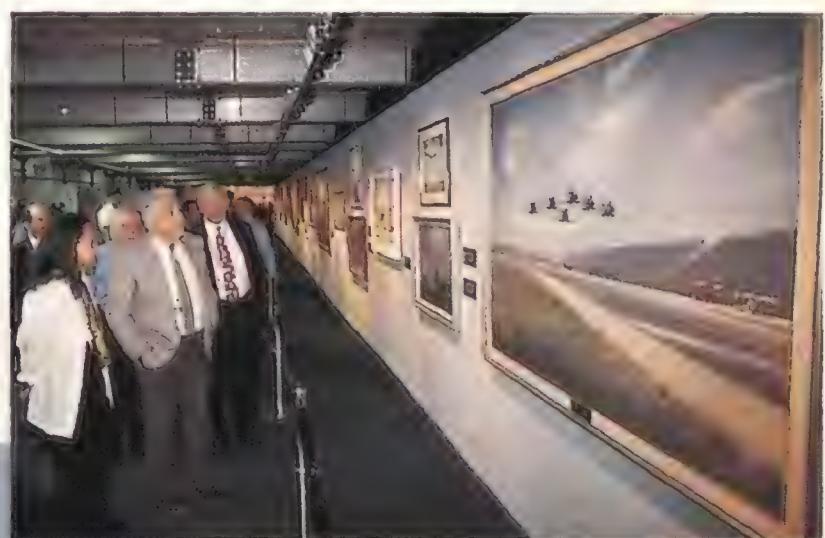
The National Air and Space Museum is hosting an exhibition of 25 of Smith's works, which will be displayed on the second floor of the Museum's east end through September 5. "R.G. Smith: The 'Old Master' of the Skies" retraces the artist's career in aviation and art. The

exhibit opens with Smith's paintings of pre-war biplanes, moves on to works portraying U.S. Navy and Marine aircraft and aviators in action in three wars, and closes with a portrait of the DC-AST, a McDonnell Douglas design for a supersonic transport that was never constructed.

Before he became an artist, Smith was an engineer. As he explains in *The Man and His Art* (Schiffer Military History, 1999), an autobiography that he prepared with his friend Rosario "Zip" Rausa, he entered the aviation industry in 1936

when he took a job as a draftsman with the Douglas Aircraft Company at a weekly salary of \$18. Smith, who stopped painting in 1996 because of health problems, is especially proud "of having participated in the conceptual and configuration phase of virtually every tactical military airplane built by the Douglas Company in its heyday." He contributed his engineering skills to the development of such classic aircraft as the SBD Dauntless, AD Skyraider, A3D Skywarrior, F4D Skyray, and his personal favorite, the A4D Skyhawk. The

"R.G. Smith: The 'Old Master' of the Skies," a new exhibit at the National Air and Space Museum (right), features 25 of the artist's works, including "Curtiss Seagull," a painting that depicts a Curtiss SOC-1 Seagull biplane landing next to the USS Mississippi during the 1930s.



ERIC LONG (2)

stalwarts of naval aviation in World War II, Korea, and Vietnam, these were also among the aircraft that Smith would later bring to life on canvas.

At the same time that his engineering career was flourishing, Smith was developing a reputation as an artist. As a youngster growing up in northern California, he loved to draw. "We had no television in those days," he writes, "so my evenings were spent either reading history or drawing, mostly airplanes." The raw talent refined in his youth proved useful early in his career at Douglas, where he was often asked to draw or paint images for corporate proposals, magazine covers, brochures, and advertisements.

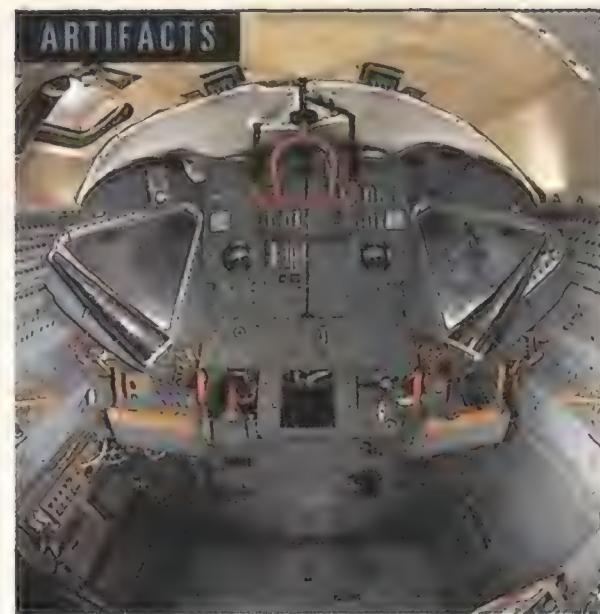
In the 1940s, Smith began to rethink his artistic style after seeing the work of Lieutenant Commander Arthur

Beaumont, whom the U.S. Navy had assigned to paint a portrait of the experimental Douglas D-558-1 Skystreak. Smith, who had already completed a painting of the all-red aircraft, was intrigued by the very different approach taken by Beaumont, a British-born artist who was known for his watercolor paintings of ships. "The overall effect was as striking as the Skystreak itself," writes Smith. "Beaumont saw in its image a variety of colors to which I had been blind. Somehow, he fused blue and other colors along the edges of the red, which highlighted rather than softened the red. He created a portrait of clarity, beauty, and realism."

It was a lesson Smith, who subsequently studied with Beaumont, would never forget. "Some artists only see an airplane as a mechanical object," he writes. "As a result their depictions of them are mechanical, stilted portraits of aircraft rather than a picture with character, motion or some measure of dramatic quality." Smith has a different approach: Rather than including every rivet of an aircraft, he strives to capture a larger sense of reality, atmosphere, motion, and energy. "If I have any gift at all," he writes, "it is for the ability to convey through my paintings, as a pilot once told me, 'exactly what it's like when you're up there.'"

During the 1960s, when aircraft design was becoming increasingly computerized and, in Smith's opinion, "no longer as much fun," he decided to phase out his career as an engineer and focus on his art. In 1968 and again in 1969 he volunteered for a month of duty as a combat artist in Southeast Asia. In his autobiography he wrote: "I experienced carrier operations in the blue waters of Yankee Station in the Gulf of Tonkin; riverine patrols along the muddy brown water of the Mekong delta; search and rescue operations in Huey helicopters; and OV-10 attack duty. I was in my mid-50s at the time, twice the age of the kids I rode with, and certainly not physically as capable. Yet I kept up with them, fueled by the adrenaline that shot through me every time the going got rough or I found myself in harm's way." It was an experience that enriched his artistic vision and increased his standing in the military community. His efforts in support of U.S. Navy and Marine Corps aviation led to his designation as an Honorary Naval Aviator, a distinction offered to only a few individuals, including General James Doolittle and entertainer Bob Hope.

"R.G. Smith is very special to all of us, and it is an honor to showcase his paintings," says NASM director John Dailey. A retired naval aviator, Dailey has made a sacrifice on behalf of the exhibit:



The lunar module on display in Gallery 112 is one of 12 built for Project Apollo. It was meant to be used in low Earth orbit to test separation, rendezvous, and docking with the Apollo command and service module. The second of two test vehicles, the lunar module was never used because the first flight was a complete success. National Air and Space Museum photographers Mark Avino and Eric Long took this photograph of the lunar module's interior using a Hasselblad 30-mm fisheye lens.

The exhibits team had to promise that a pair of his favorite Smith paintings would be returned to their usual place on one wall of his office as soon as the exhibition closes.

—*Tom D. Crouch, aeronautics curator, National Air and Space Museum*

MUSEUM CALENDAR

June 3 & July 1 Evening Stargazing. Join NASM astronomer Sean O'Brien for a look at summer's celestial sights. Activities will begin at dusk at Sky Meadows State Park near Paris, Virginia. For information and directions, call (540) 592-3556.

June 9 Book Signing. Join some of the Museum's curators and photographers as they autograph copies of their books. Museum Shop, 1:30–3 p.m.

June 12 Wernher von Braun Memorial Lecture: "Space and the New Millennium—A View from Capitol Hill." Senator Barbara Mikulski will talk about the U.S. space program's role in creating new educational and economic opportunities. Langley IMAX Theater, 8 p.m. Tickets are available through PROTIX, phone (800) 529-2440, and on the Web at www.protix.com.

June 14 Book Signing. Apollo 11 astronaut Buzz Aldrin will be signing

copies of his new science fiction book, *The Return*. Gallery 100, 11 a.m.–2 p.m. and 2:30–4 p.m.

"Back to the Moon." Alan Binder, principal investigator for the Lunar Prospector, an unmanned spacecraft whose goal was to confirm the existence of frozen water on the moon, discusses the mission and what its results mean for the future. Einstein Planetarium, 7:30 p.m.

June 24 Hands on History Day: "From Airmail to Airlines." Travel back to the time between the world wars and relive the glamour of aviation's Golden Age. Information Desk, 10 a.m.–3 p.m.

"Astronomy You Can See!" NASM lecturer Patty Seaton reveals how to mark time by the stars and explains how to measure a star's brightness, temperature, and age. Einstein Planetarium, 6 p.m.

July 4 Fourth of July concert by the U.S. Air Force Band and Singing Sergeants. North Terrace, 6 p.m.

July 8 & 9 Family Activity: "You Can Fly." Learn how to become a pilot by talking to representatives from aviation groups. Gallery 100, 9:30 a.m.–6 p.m.

July 29 "The Circle of Animals—Tales of the Zodiac." Staff astronomer Sean O'Brien discusses the tales behind the zodiac constellations. Einstein Planetarium, 6 p.m.

Paul E. Garber Preservation, Restoration and Storage Facility. Get a behind-the-scenes look at the workshop in Suitland, Maryland, where skilled craftsmen restore air and space artifacts. Free tours Mon.–Fri. at 10 a.m. and Sat. and Sun. at 10 a.m. and 1 p.m. For reservations, call (202) 357-1400; TTY: (202) 357-1505.

Except where noted, no tickets or reservations are required. To find out more, call Smithsonian Information at (202) 357-2700; TTY (202) 357-1729.

National Air and Space Society

As a Founder Member you can help support the most significant effort in the National Air and Space Museum's history: the new Dulles Center, to be built at Washington Dulles International Airport. For information, call (202) 357-3762 or write to: The National Air and Space Society, NASM, Room 3608, MRC-310, Smithsonian Institution, Washington, DC 20560; e-mail: nass@sivm.si.edu

Deep-Sea Fishing

In the Atlantic Ocean about 300 miles from Cape Canaveral, Florida, a war between lift and weight was being waged in July 1961 as Marine pilot Jim Lewis struggled to keep his recovery helicopter in the air. The rotor blades of his overloaded chopper clawed at the humid air as over 8,000 pounds of dead weight called *Liberty Bell 7* threatened to drag the aircraft with it to the bottom of the ocean. Virgil I. "Gus" Grissom, pilot of the Mercury spacecraft and just recently the United States' second man in space, was well on his way to being the nation's first space fatality, an honor he was trying to avoid as he begged for help in his waterlogged spacesuit. Finally, Lewis ordered his copilot to cut the cable and called for another helicopter to haul Grissom from the water. The capsule sank to the ocean floor.

Thirty-eight years later at the same site, different factions skirmished. On one side were time, money, and weather; on the other, a search-and-salvage team I was leading. We were struggling to find McDonnell Capsule No. 11, still lying where it fell after Lewis jettisoned it following Mercury-Redstone Mission No. 4—the only manned spacecraft NASA had not recovered.

I had spent 14 years researching the capsule's location by studying radar and weather data and interviewing those who had watched the capsule sink, and trying to secure funding to recover it. Finding a sponsor had proved nearly impossible. But in late 1998, Mike Quattrone, senior vice president and general manager of Discovery Channel, agreed to supply the funds to hire Oceaneering International, a search-and-salvage company that could help me pinpoint and retrieve the capsule. In return, Discovery Channel would have full access to the operation for an "Expedition Adventure" documentary.

One cloudy day last May we had just shifted our ship, the *Needham Tide*, 150 feet to the west on the search grid, which covered 24 square miles northeast of the Bahamas. By that time, we had spent

seven days searching the grid and I had concluded that the expedition was going to be a total failure. The Magellan 725, a 5,500-pound remotely operated vehicle equipped with four video cameras, had been on the bottom—some 16,000 feet below—for almost five hours, and we had yet to even locate the first target previously picked up by a side-scan sonar ROV. The terrain could not have been worse. Using the Magellan's cameras and sonar (which was on the fritz), we could see only as far as the next sand wave, maybe 30 or 40 feet at best. I also knew what was going to happen: We would fool around a little more on the bottom, find nothing, and be forced to haul up the Magellan because of bad weather. Sea conditions would shut us down for several days, and by the time it was good enough to make another ROV dive, our allotted two weeks would be up. We would have found the 88 targets the sonar had

identified in the search grid, but we would not have had the time on site to find out if *Liberty Bell 7* was one of them.

Only a few minutes later sonar technician Mark Wilson noticed some small returns on his equipment. "What have you got?" I asked.

"Hard to say, just some small contacts farther to the west," he said. We headed over that way.

I was already tightly wound from the expedition's numerous highs and lows, and now I was coiled and ready to strike at the smallest provocation. The thought of having to explain to the news media why we were unable to find the capsule made my stomach flip-flop.

The Magellan, bouncing along on a tight tether, slowly started probing up a small rise. On the color video screen, the targets appeared to be a line of small white clumps. *What do we have here?*

In front of the ROV was some light-colored material. In 25 years of undersea operations I have used remote technology to do everything from inspect an oil production platform to raise wreckage from crashed aircraft, but this looked like nothing I have ever seen.

"Any ideas?" Wilson asked.

"It almost looks like a chunk of ice or something; might be crumpled aluminum from that crashed airplane to the north," I said.

"Well, there's more of it up the hill and I think I'm getting a larger target behind it all," Wilson said.

The trail of debris continued as the Magellan clawed its way up a small rise.

"What is that stuff?" I asked.

"I logged it as aircraft wreckage," Wilson replied.

As the vehicle continued to the crest of the hill, I could barely make out something tall, about 30 feet away. Whatever it was, it was dark in color—it



DISCOVERY CHANNEL

Mission accomplished: Expedition leader Curt Newport gives Liberty Bell 7 the once-over after winching it off the ocean floor.

wasn't reflecting much light.

The dark shape began to resolve as the Magellan struggled toward it. I had initially assumed it was a section of aircraft wreckage stuck into the bottom, maybe a piece of wing.

"Boy, it's got some height to it," I muttered. *It's about the right size...No...It can't be the capsule!*

The Magellan and its cameras crept closer still. The vehicle was bouncing off the bottom as it pulled against the tug of the umbilical. My knees weakened. I was almost climbing on Wilson's back, as though getting closer to the video screen would make the object more visible.

The shape loomed a little closer. My heart rate accelerated. Damn! Could it really be?

"Oh my god." Is that white lettering on the side of it?

I could just make out the conical shape of the object. The exterior looked rough and—corrugated? The words "UNITED STATES" blazed through the glass of the video monitor.

The capsule!

We could see the lettering, the landing bag straps, the extended periscope—all of it. It looked like it was ready to fly again. I buried my face in my hands. "I don't believe it. The first target! This never happens!" I was shaking with excitement. The other crew members were all grins: After so many problems we had found what we were looking for.

The massive ROV hovered 30 feet from the capsule, hydraulic pump whining, propellers churning, sonar head ticking as it cast a warm glow on the spacecraft, which sat slightly tilted on a pile of white powdery material, the base ringed with loops of landing bag straps. The ROV was bouncing harder now as it continued to tug on the tether tying it to the ship.

"Look at that! You can see the periscope!" I gushed as the Magellan inched closer.

It had been nearly four decades since human eyes had viewed *Liberty Bell 7*. Now four sets of them were examining the craft's every crevice. Beside the capsule's optical periscope, a silver string dangled—helicopter pilot Jim Lewis' old recovery line.

As the ROV pilot fought to maneuver the Magellan around the base of the capsule, the vehicle's lateral thrusters thrashed the deep water, using 100 percent power to circle around so we could examine the backside of our discovery. I watched and waited, wondering if the other side of the capsule was even there. For all I knew, the sound-fixing-and-ranging bomb mounted on *Liberty Bell* had detonated and blown a huge section of the spaceship to bits. The device, which

contained 11 ounces of HBX (a powerful explosive similar to TNT), was designed to detonate at a depth of 4,000 feet if *Liberty Bell 7* sank, alerting NASA to its location. But the declassified documents I had uncovered suggested that the bomb had not exploded as it should have. My fears were unfounded: The back of the capsule was intact. I knew now that we had a spacecraft fitted with an unexploded bomb, one powerful enough to destroy the capsule and anyone around it.

Slowly, the words "LIBERTY BELL 7" lit up under the ROV's powerful lighting as though they had been written with Day-Glo paint. A light bulb went off in my head. "The white pile of powder—that's what's left of the beryllium heat shield," I said. "Those chunks of material we saw down the hill are pieces of the heat shield."

It was obvious. As the heat shield disintegrated over the years, chunks of it had broken loose and tumbled down the small rise like snowballs. You could even see tracks in the bottom where they had rolled.

We spent 53 minutes examining the capsule before starting to reel in the Magellan and rescue it from the elements. But our elation over our find was soon dashed. We lost the struggle with the rough seas when the Magellan's cable snapped. Now the submersible lay at the bottom of the sea, at least for the time being.

About two months later we returned. Using the new ROV Ocean Discovery, we managed to haul *Liberty Bell 7* to the surface on an expedition as frustrating as the first: It took us three days just to find the capsule again. Lacking a navigation system that allowed us to determine where it was in relation to the ship three miles above it, we had to estimate its position based on the heading of the ship when we found it and the amount of tow cable we had deployed.

In the early morning of July 20, 1999, Grissom's spacecraft finally cleared the surface. Two technicians from UXB International, an ordnance and explosive waste remediation company, removed the deadly bomb, deeming it "armed but unexploded." Because attempting to disarm it would involve unnecessary risk, and returning to port with an explosive device on board was out of the question, we heaved it over the side after taking a few photographs.

Following several months of restoration at the Kansas Cosmosphere and Space Center, *Liberty Bell 7* will start a three-year tour beginning with the Kennedy Space Center Visitor Center this month, a location not far from where it left Earth almost 40 years earlier.

—Curt Newport

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Manhattan Transfer

The photograph at right evokes a Golden Age of air travel. Dirigibles would cross the Atlantic, then appear over Manhattan and glide up to the Empire State Building. After a dirigible docked at the world's tallest building, passengers would transfer from airship to skyscraper, and an elevator would whisk them to street level. Through it all, New Yorkers would be treated to the awesome sight of a lighter-than-air behemoth hovering overhead.

The only problem is that the photo is a fake. The artful composite illustrates nothing more than the wishful thinking of financier John J. Raskob and former New York governor Al Smith, the pair that spearheaded the creation of the Empire State Building in the late 1920s. Previously, the building was to top out at the 85th floor, with a flat roof. But the story goes that Raskob looked at a scale model one day and declared, "It needs a hat." After all, the rival Chrysler Building was crowned with a distinctive stainless steel spire.

Unadorned, the Empire State project would reach higher than the Chrysler, but only by a few feet. The addition conceived by Raskob's team would add another 200 feet—and it would serve more than a mere ornamental function: It would become a unique airport in the sky.

With legendary showmanship, Al Smith extolled the building taking shape, including its airship-docking role. The press chimed in with talk of "a sensational new era in the history of aviation." By opening day, May 1, 1931, the masonry structure sported a cylindrical mooring mast, done up in chrome-nickel steel and faceted glass.

The Empire State Building was completed on time and under budget. Yet for such a well-thought-out building, it was remarkably unprepared for its role as aviation pioneer. Granted, the building's framework was stiffened against the 50-ton pull of a moored dirigible, some of the winch equipment for pulling in arriving ships was installed, and the 86th floor was readied with space for a departure lounge



and customs and ticket offices. The builders' lawyers even prepared a thick brief, arguing, among other things, that owners of neighboring buildings could not sustain a claim of trespass when they found dirigibles overhead. But no one worked out one other problem: wind. The steel-and-glass canyons of Manhattan are an airship captain's nightmare of shifting air currents. Raskob and Smith were inviting the unwieldy craft to come in low and slow, over hazards such as the menacing Chrysler Building spire, and somehow tie up without use of a ground crew. Then, too, if the crew released ballast to maintain pitch control, a torrent of water would cascade onto the streets below. And once secured, a dirigible could be tethered only at the nose, with no ground lines to keep it steady.

Passengers would have to make their way down a swinging gangway, nearly a quarter mile in the air, onto a narrow open walkway near the top of the mast. After squeezing through a tight door, they would have to descend two steep ladders inside the mast before reaching the

elevators. "Can you see some 75-year-old dowager doing that?" asks Alexander Smirnoff, the current telecommunications director of the building, as he stands on that walkway.

Confronted with such daunting realities, Smith dispensed bland assurances that "there must be some way to work the thing out." He insisted that the U.S. Navy was a partner in the project and its dirigible *Los Angeles* would dock at the mast. But the Navy remained mum. The most it did was allow one of its smaller airships to hover nearby one day at the request of a newsreel company.

Passenger airship service was the province of Germany's Zeppelin Company, and its head, Hugo Eckener, did not hide his skepticism. That's fortunate for New York. Just imagine if the hydrogen-filled *Hindenburg* had exploded over midtown Manhattan instead of Lakehurst, New Jersey.

Eventually, the press' initial enthusiasm for the docking scheme began giving way to concerns about risk. A Philadelphia newspaper wrote, "Basically the proposal to dock transatlantic airships...hangs on the highly dubious contention that the saving of an hour's time to thirty or forty travelers is of more importance than the assured safety of thousands of citizens on the streets below."

One small airship did drop a long rope to the mast and held on from a distance for a precarious three minutes, and another delivered a bundle of newspapers by rope. After that, the effort was quietly abandoned. But the mast remained, and it eventually became an asset, turning out to be a spectacular radio and television transmitter. It also provided two popular and lucrative observation decks. And it gave the Empire State Building an unforgettable profile.

Finally, the mast became an enduring symbol of human folly. John Tauranac, author of *The Empire State Building: The Making of a Landmark*, called the airship plan "the looniest building scheme since the Tower of Babel."

—Lester A. Reingold

"I can't wait to get to the next building and see what's there!"

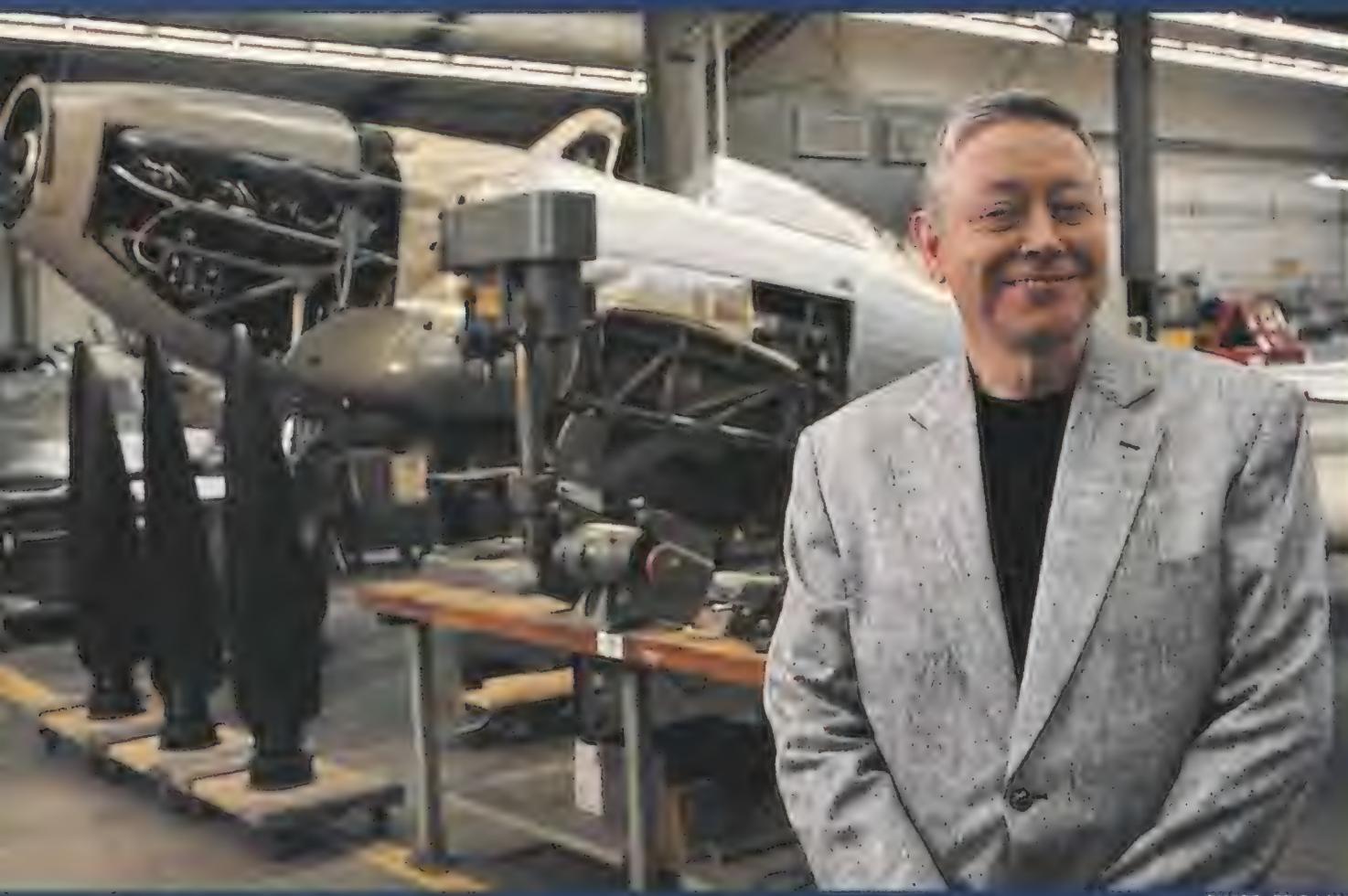


PHOTO: ERIC LONG

"Being part of the Smithsonian Legacy Society is one of the most rewarding things I've ever done."

—EARL CLAYTON and the legendary Hawker Hurricane at the Smithsonian's Paul E. Garber Facility, one of Earl's favorite places in the world.

When Earl Clayton tells co-workers he's going on vacation, they ask, "To see airplanes again?" You see, Earl is a genuine lifelong aviation buff. He's happiest gawking the buildings of the Smithsonian's Paul E. Garber Preservation, Restoration and Storage Facility, which houses the majority of the National Air and Space Museum's collection.

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Birds Do It Better

In Ken Dial's Montana laboratory, feathers fly.

by Adele Conover *Photographs by Chad Slattery*

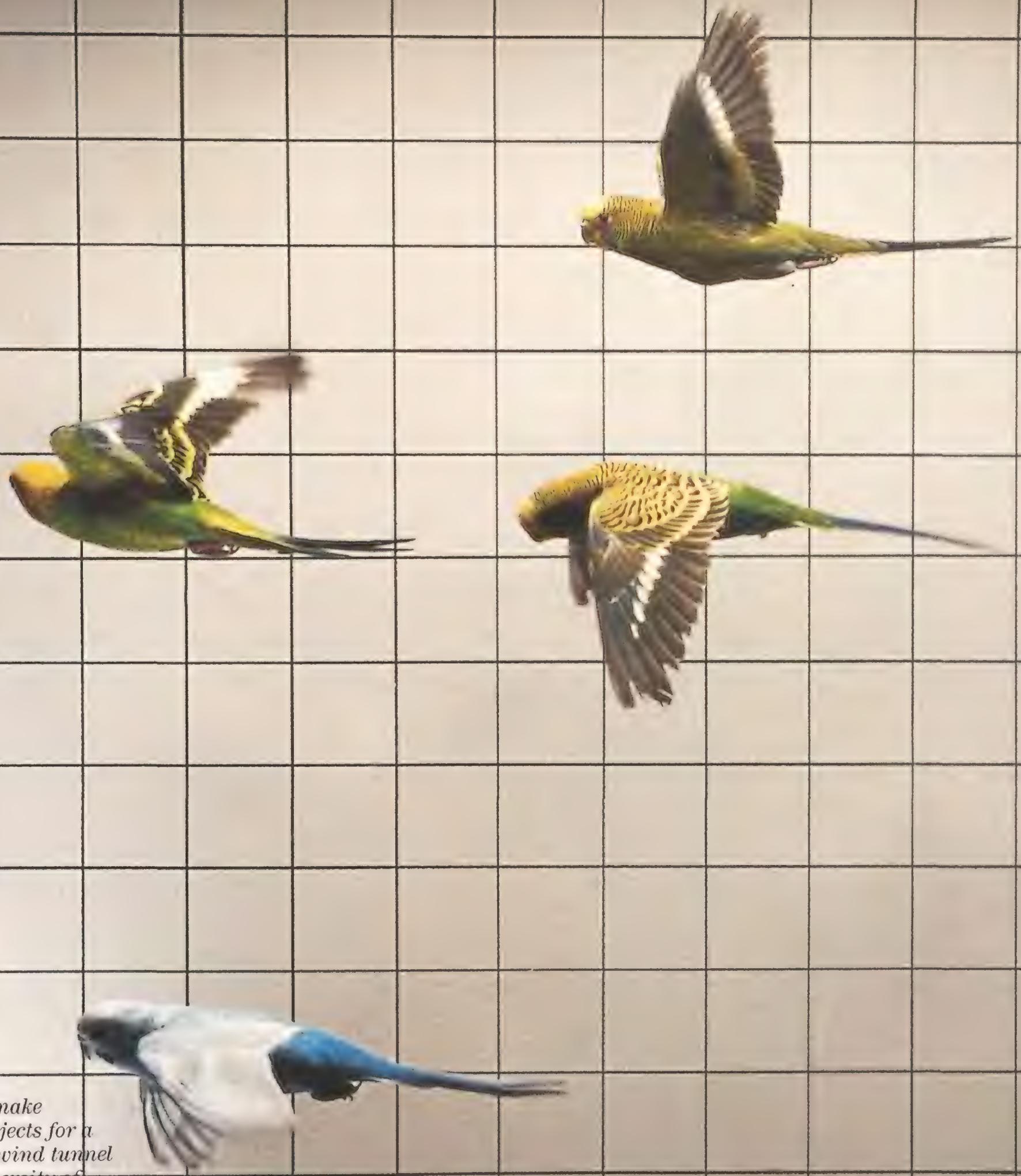
It may come as a surprise to the Wright brothers and every pilot and aerospace engineer since, but according to University of Montana flight biologist Ken Dial, "At last we are learning how to fly!" Using measuring tools such as tiny electrophysical and biomechanical recording devices, cameras that take three-dimensional images, and high-speed X-ray motion analysis video, Dial and his colleagues and students at the University's flight laboratory have done what no other researchers have: They have looked into the body of a live, flying bird and listened to it "talk."

And the flight of birds is anything but wordless. At the flight laboratory where he works, Dial's investigations have begun to explain how avian muscle, feather, and bone launch a bird, thrust it through the air for both long and short distances, land it on a dime, and perform aerobatics that any

Blue Angel would envy. The findings coming out of Dial's flight lab may help aeronautical engineers design more maneuverable aircraft based on the aerodynamic performance of such heretofore unheralded birds as starlings, pigeons, magpies, and budgies. Dial sees his research as ripe for collaboration between flight biologists and aeronautical engineers.

"If the number of animals that fly in the air is any indication of the future success of aerospace, the outlook is very bright indeed," Dial told a recent meeting of the Society of Experimental Test Pilots. "Flying is Mother Nature's preferred mode of locomotion. And her flying machines are among the most successful on Earth—after all, they have been at it for millions of years."

Dial told the gathering of test pilots that his lab's research began with an understanding of the basic aerodynamics of wings. By comparing the dynamics of



Parakeets make worthy subjects for a flight in a wind tunnel at the University of Montana, where scientists are seeking to understand how the delicate creatures fly so efficiently.

Flight biologist and pilot Ken Dial has been fascinated by birds and airplanes since he was a boy. After years of investigating a variety of avian species, including the 22-pound mute swan (below), Dial would like to see aeronautical engineers make aircraft more bird-like.

rotary- and fixed-wing craft to avian maneuvering, the researchers came to an appreciation of why birds are more agile: They are far more unstable. The lab investigated how a bird's neuromuscular control system allows it to quickly alter flight surface areas—such as wings and tail—to respond to changing flight conditions. A bird knows to change shape because it has a body-wide sensory feedback system: 4,000 to 10,000 feathers. The feathers respond to air passing over them by, lever-like, nudging a sensory neuron at the feather's base. The neuron sends an impulse to the bird's central nervous system, which in turn stimulates various muscles and feathers, causing them to move in a way that maintains stable flight and a proper orientation.

A bird's neuromuscular control system is analogous to the computers that make flight possible in inherently unstable aircraft such as the X-29 and X-30. Although the pilot has ultimate control of the airplane, he cannot possibly keep up with all of the tiny adjustments that must be made during high-speed flight. The computers react to the

data coming in and order all the necessary adjustments—almost like a primitive nervous system—freeing the pilot to make the big decisions.

Flight has been on Ken Dial's mind ever since he was a kid growing up next door to Los Angeles International Airport, "sitting on the fence watching planes." He was also a bird watcher, roaming the salt marshes and hills near his home in southern California. Dial is a large man with an expressive face that is further amplified by his lack of hair. Self-described as an "Angeleno with attitude," he has something of a star quality.

Consequently, he is the host of "All Bird TV," which is part of Discovery Communications' Animal Planet nature series. And for Dial, nothing is too wacky to get his point across on the subject of birds and flight: He has dumped his head into a bucket of red glop to demonstrate how baldness in vultures is a virtue (dipping one's head into the cavities of dead animals could present problems for feather maintenance). Dial also dons large wings to



illustrate how birds alter the angle of their wings in flight.

"Most animals do fly," marvels Dial. "There are more than a million species of flying insects. Among warm-blooded animals, of the 13,000 living vertebrate species of birds and mammals, 10,000 [9,000 birds, 1,000 bats] are airborne." According to energy-cost research studies of animals done by aerodynamics engineer Vance Tucker in the early 1970s, flying is the most economical means of locomotion, beating walking, trotting, and running. "Mother Nature is very much in the business of cost efficiency," says Dial. "Her currency is measured in units of metabolic energy, and with respect to maneuvering a body efficiently through space, birds represent one of her finest experiments."

Dial's work has revealed that a starling can zip through the air at 120 body lengths per second. Relatively speaking, starling speed makes the 32 body-lengths-per-second progress of a Mach 3 Lockheed SR-71 Blackbird look glacial. The fastest terrestrial animal on Earth, the cheetah, lopes over the ground at a poky 18 body lengths per second, and humans positively trudge at three to four body lengths per second. No wonder they sought to take to the air.

Five centuries ago, Leonardo da Vinci attempted to make human flight a reality by watching birds, taking careful notes, and dissecting the muscles of bird carcasses. Ornithopters (wing-flapping aircraft) were his answer, and he designed numerous models on paper. The Wright brothers took note of birds as well. They liked to observe buzzards, hawks, eagles, and crows, noticing how the birds altered the angle of their wings when they wanted to turn. Consequently, the Flyer had controls to warp, or twist, the wing, allowing the biplane to bank right or left. The Wrights' warping wings evolved into airplane ailerons, movable flaps on the trailing edge of the wing that pilots can move up and down to initiate a turn. Ken Dial and the workers in his lab are in the genre of Leonardo da Vinci and the Wrights. However, instead of being observers from the outside, bird-watching with Ken Dial means "sneaking inside a bird," as he puts it.

After sedating his subjects under general anesthesia, Dial surgically implants minuscule sensors that record activity produced by muscle movement. Tiny strain gauges detect the amount of force muscles exert during flight by measuring the bending



of bones where they meet muscle. The bird's flight data goes directly into a computer via a thread-like cable. Judging from the performance of Red, a starling, and several of his fellow subjects, who demonstrated flying in a wind tunnel, the birds seem nonchalant about the whole affair.

Dial also peers inside birds in flight by using a high-speed—200 to 400 frames per second—X-ray camera that yields three-dimensional images. Through conventional high-speed photography of the external bird in flight, scientists already knew that the wing—specifically, its airfoil—changes shape during flight, presenting a broad area at the beginning of the downstroke to create lift and keep the bird aloft, while flexing back into the body on the upstroke.

In 1988, to gain his first insights into the biomechanics of bird flight, Dial, then a research fellow at Harvard University, began working with anatomist Farish A. Jenkins and Brown University's G.E. (Ted) Goslow. The researchers taught starlings to fly in a wind tunnel that Dial had helped build, and filmed them with an X-ray camera that enabled them to see through the birds' feathers and skin to view the skeleton in action.

"To our amazement we found that when a starling flew, its skeleton is full of springs that can store and retrieve energy elastically," says Dial. A bird's wishbone, a fused version of our collarbones, and its carina, a keel-shaped part of the breastbone, move with each wingbeat. With every downstroke the wishbone is compressed, but it recoils as the bird's wing is pulled into



A breathing-mask-clad parakeet is readied for a flight in the wind tunnel, during which its oxygen consumption will be measured. Before the flight, graduate student Matt Bundle weighs the cooperative subject.



At the university's field research station, Dial uses a large net to recover birds after test flights.

A natural educator, Dial has no reservations about using a pair of man-made wings to demonstrate avian flapping motions.

the body during the upstroke—sort of the reverse of making a wish with a wishbone but letting go before the bone breaks. The starling's skeletal spring system enables it to fly efficiently and conserve its metabolic energy.

Of major significance to Dial's work is his measurement of the mechanical power output, or horsepower, of a bird as it flies at different speeds, including hovering. "Scientists in the past have attempted to measure 'fuel consumption' of a bird by measuring its oxygen consumption while it wore a mask," says Dial. "However, until recently no one was able to determine the horsepower or mechanical power output of a bird until we did so by using our implanted microbiomechanical sensors while the birds were flying over their full range of flight speeds."

Even the lab technique used for oxygen

studies seems daunting. Matt Bundle, one of Dial's graduate students, demonstrated the problem by trying to persuade Red, the starling, to consent to wear a tiny oxygen mask while flying in the wind tunnel. No way. (Bundle is one of the first to measure aerobic capacity in birds. His first experiments included keeping up with a running rhea, a huge flightless bird, as well as coaxing it down to a walk.)

In 1996, Dial and then-graduate students Bret Tobalske, Doug Warrick, and Andrew Biewener set out to study mechanical power directly. They drafted several black-billed magpies into service. (Almost all of the birds Dial and company use are abundant locally. The birds are trapped wild and later restored to their habitat in the Missoula countryside.) Outfitted with strain gauges and filmed with high-speed cameras, the magpies revealed their secrets.

In the past, flight biologists had predicted that the power required for an animal to fly over several speeds would be similar to that required by an airplane, which starts out using a lot of horsepower to take off. Power requirements flatten out, however, as the airplane maintains a steady speed. But if the airplane continues to increase its speed, fuel consumption increases. On a graph this would appear as a U-shaped curve.

What Dial and his researchers found is that hovering magpies were indeed at maximum power as predicted by the U-shaped curve. But when they flew swiftly, they used far less power than expected, suggesting that it was cheaper energetically to fly fast than hover. The reason, says Dial, is that magpies have the ability to change shape while flying; they can spread out tail and wing feathers, forming a sort of hang-glider wing, or fold the feathers in to assume the shape of a rocket. Consequently, the power requirements turned out to be more of an L-shaped curve. "It may be expensive for a bird to hover and fly slowly, but a bird's minimal power output doesn't seem to change dramatically over a wide range of their flight speeds," says Dial. "An airplane doesn't do this because it can't change shape. A plane can't change from a rocket to a 747 to a gigantic cape-like blanket spun out from the wings of the body."

In addition to magpies, starlings have had a long and distinguished career in Dial's research, logging thousands of hours in wind tunnels. Tobalske found starlings "very smart" and not above a joke now and then, "including interrupting a wind tunnel

session by hopping on each other's backs." The common pigeon is another species that has advanced Dial's knowledge of bird flight, though in a manner different from starlings. "The pigeons didn't like the wind tunnel but were happy enough to fly down a corridor from one perch to another," says Tobalske.

"Pigeons are very impressive," says Dial. "They are so muscular they remind me of Arnold Schwarzenegger. They have humongous muscle, which they need not only for long distance flight, but because they evolved around cliffs. They have to maneuver in tight places. That's why they adapted themselves to the city so well. Window ledges feel like home. As pigeons breed year-round, competition is high—males constantly vying for females—they have to show off. If she takes off straight up, he has to take off too."

To detect how the pigeon's muscles allow it to maneuver so well at low speed, Warrick and Dial placed tiny reflectors on the pigeon's wings and tail surfaces. Then, using a 3D motion analysis infrared camera, he filmed the pigeons in action as they flew down a 50-meter stretch in the hall outside Dial's office. The course was designed so that in their quest for perches, the pigeons had to thread their way through a series of obstacles in the form of see-through hanging acetate curtains. The idea was to discover how a pigeon maneuvered at low speed—a particularly demanding phase of flight.

Warrick had assumed that pigeons would move their wings in the traditional ways: To initiate a bank to the left, a gliding bird will pronate (palm down) the left wing, reducing the amount of lift it generates; then the bird would increase the lift produced by the right wing by supinating it (palm up)—just like a pilot would do with ailerons on the right and left wings of an airplane. Warrick reasoned that the increased lift on the right wing and the decreased lift on the left wing would produce a torque that rolls the bird into the bank.

But things turned out rather differently. In the video of Warrick's work, the birds appear to be maneuvering in a kind of controlled flailing—what Warrick describes as "brutish" rather than a "nice subtle movement." What was really happening, he says, is the pigeon initiated a turn to the left by beating the right wing faster for the first half of the downstroke, generating more lift on the right side and causing a roll to the left. But then the pigeon must find some

way of arresting and controlling the roll to the left so that it does not flip upside down. It does this by beating the left wing faster during the second half of the downstroke, allowing the left wing to catch up with, or equalize, the lift produced by the right wing. "The angular accelerations in roll [the pigeon] creates using this mechanism are in excess of 2,000 degrees per second squared," says Warrick. "These pigeons are bludgeoning their way through the air to maintain positive control at a low speed."

Although this kind of maneuvering is energetically expensive, it's done only for brief periods of time. Says Warrick: "It's worth the investment in energy and labor considering the alternative"—getting nailed by a predator or crashing into the intended landing spot.

Small birds can pull off amazing maneuvers an aeronautical designer would love to duplicate. The A-4 Skyhawk jet, which rolls at 720 degrees per second, looks lethargic next to a barn swallow, which has



An anesthetized goose (below) is implanted with a biomechanical sensor (left), which relays data collected during flight to a computer.





Bundle drops a perch to release a flock of parakeets into the wind tunnel.

a roll rate in excess of 5,000 degrees per second. Warrick measured this swallow roll rate from videos of the birds catching flies.

Birds can also stand G forces far above what humans can tolerate, and they do it hundreds of times a day. Calculations have shown that birds can withstand up to 14 Gs. Based on radar gun data, which Warrick recorded while filming foraging swallows, the little birds make 5-G turns as a matter of course. "They do it all day long," he says. "When they're feeding young, a swallow might pull a 5-G turn every five seconds. That's five to ten thousand turns every day."

One reason for the stamina of swallows is their extraordinarily high metabolism and aerobic fitness. "But more important, perhaps, is the fact their heads are not above their hearts during these turns so there is little tendency for the blood to drain from their heads during the turn, as is the case for airplane pilots," says Warrick.

Dial, a commercial pilot with instrument and multi-engine ratings, is envious of birds' physiologically perfect suitability for flying. During a flight in a Cessna 172, "we [human fliers] have to have all of this," he says, waving his arm past the cockpit's busy display of instruments. A mile up, we tour the air surrounding Missoula. "A bird has the most sophisticated stabilizing cockpit—its head, which includes its eyeballs, its ears, and its brain, all connected to the body by a very long neck or cervical vertebrae," he says. "We are all wowed by the fact that an owl standing on a branch can turn its head nearly 360 degrees. All birds can do that, and they do it while they are flying. The head is perfectly level while the body twists and turns, oscillates, and changes shape. Every flying bird holds the cockpit level to the horizon while the machinery of

flight turns and twists depending on what they are doing.

"We can learn a ton from birds on how to take future aircraft and have them land on much smaller ships than the big expensive aircraft carriers, because birds have the ability to stall very quickly," he says. "These can be unmanned vehicles, which are really hot right now with NASA and DARPA [Defense Advanced Research Projects Agency], who are looking into making small maneuverable aircraft. We are going to be able to learn how to control these devices so they can land on a heaving flight deck at sea like a bird on a tree."

As we fly over the magnificent Montana landscape we see tiny deer, a few minuscule elk, a clump of bison. In the distance are the Mission Mountains and beyond that the vast Bob Marshall Wilderness. Dial points out the original outline of the old Lake Missoula, an enormous lake that resulted from the breakup of ice dams some 15,000 years ago. The Flathead Lake and kettles and ponds are all that remain. "I still get chills to see the tops of peaks and see all these little habitats," says Dial.

"Small birds are the model flying machines," he continues. "Little birds like passerines dominate the bird world, rather than eagles and other big fliers. There are at least 5,000 species of little birds because their behavioral biology is based on power-to-mass performance. Why do you think there aren't any elephant-size birds? As mass goes up, power [to leave the ground] goes down." Clearly, for a flying machine, bigger is not better.

Not far from the main campus, we fly over the field research station. Built in 1901, the 9,000-square-foot building was once the Fort Missoula horse stable for the U.S. Cavalry. Now it has been remodeled into a research facility, which houses Dial's new lab. No longer will Dial and his colleagues have to use the hallway outside his office to observe birds in flight. (The acetate curtains, however, are still rolled up on the ceiling in the office should they be needed again.) The field research station, surrounded by a hundred acres of land, adjoins the largest expanse of wilderness surrounding any university in the lower 48. That means plenty of room to tackle the mysteries of avian flight. There are classrooms, offices, a surgery room, a bio-acoustic analysis room, a sophisticated computer system, and other facilities. The current residents include wild mute swans, Canada geese, and a flock of

passerines, all residing in airy flight cages.

At the moment Dial and his students are in the process of seeing how mechanical power output is influenced by the size of a bird's body. They are studying a group of birds that includes the teal duck, which weighs a wispy five ounces; the mallard duck (two pounds); the Canada goose (eight pounds); and the mute swan (20 to 24 pounds). Since the mallards, geese, and swans are too big to fit in the wind tunnel, the new lab has a long runway, which opens out to Montana's big sky via a large garage-like door. The birds, wired to collect data, are captured by a large net after their flight down the runway.

Unlike Red and the other starlings, these birds want nothing to do with visiting humans, and that's the way Dial likes it. "We want these birds as wild as can be so we can really see how fast they move in space avoiding a predator," he says. "It's a race between predator and prey: Are the birds going to take one step to take off and escape or two or need a long runway, which gives a predator more time to strike."

Dial finally manages to corral one of the immense mute swans, giving me a chance to feel the pronounced camber of its wing. The wing seems incredibly powerful, so I assume that this bird must be a powerful flier, but Dial says it's just the opposite—at

least compared to smaller birds—because of the power-to-mass ratio. "We can see why a teal can fly off like a bat out of hell, and why a swan when it takes off looks like it's flying through molasses," says Dial. "When the swan takes off, it is really pushing at the end of the envelope of being able to fly. Once you get larger than that, you begin to find out, with our gravitational forces coupled with Mother Nature's muscle performance, that we've reached the limit. I believe that we have on Earth today birds as big as have ever lived—who could take off from the ground. The American turkeys, the swans, the kori bustards of Africa, the wandering albatross, and the Andean condor are the big five, and they all converge on the same mass and it's not coincidental. They converge on the same mass because that's where the [bird's] 'engine' runs out of fuel."

Dial himself never seems to run out of fuel. One of his next projects is to figure out how the birds he calls the marathon fliers, such as the bristle-thighed curlew, migrate—apparently non-stop—from Alaska across the Pacific to perhaps the Hawaiian islands or even down to Fiji. "They would have to fly for three to five days without landing," he marvels. But that is another story and the next stop on marathoner Ken Dial's flight plan. —

Dial would tell you that his Turbo Commander, which he uses for business trips to Los Angeles, is a much less efficient flier than the birds he studies.



The TRUTH is Down Here

**How to be sure Earth-viewing satellites tell the straight story?
Get down on the ground and check.**

by Bijal Trivedi

Every day for more than a year, Ane Alencar bounced her jeep across the potholed dirt roads of Para, Brazil, past miles of silent, ash-black pastures. In the dusty dry months and in the rainy season, when the roads became rivers of mud, she drove to remote farms and cattle ranches to document how much of the rainforest landowners had logged or burned. She'd seen it already, but then again she hadn't. Alencar's treks were part of an experiment to determine whether satellite data—in this case Landsat photography of deforestation in the Brazilian Amazon—was accurately portraying conditions on the ground.

The work began after Daniel Nepstad, a field ecologist at the Woods Hole Research Center in Massachusetts, noticed discrepancies between satellite pictures and his own field experience studying forest recovery on abandoned farms in the Amazon. Landsat, it seemed to him, was missing huge gashes of forest that he knew had been destroyed by burning and logging. If true, it meant that Landsat-derived estimates of deforestation—the kind most commonly used by scientists and governments—were far too low.

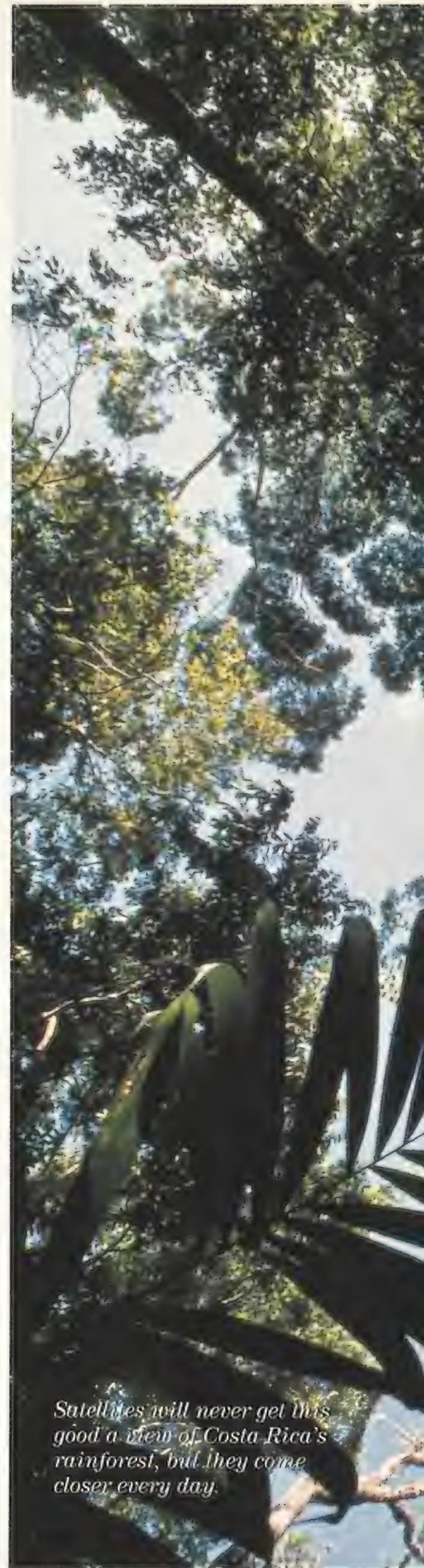
Nepstad enlisted field teams from the Amazon Institute of Environmental Research, where Ane Alencar works, to do 200 household interviews. Another Brazilian research institute helped interview 1,400 sawmill operators. In three years, the teams surveyed properties covering 3,500 square miles of territory. "The [landowners] talked to

me gladly," Alencar says. "Some would invite me for dinner, some proposed marriage, some would try to convert me to their church. I couldn't do this work only asking about satellite maps, burning, and forest fires. I first had to get into their life."

Eventually she would pull out satellite pictures and show them to her hosts. At first they couldn't understand the images, but then they would say, "Oh, this is my pasture" or "That's my forest." Alencar would ask the owners to sketch areas on the map that had been logged or burned.

Three years of this kind of patient ground work confirmed Nepstad's suspicions: Landsat pictures were missing at least half the areas actually being destroyed or damaged. It turned out that mild disturbances like light logging or pasture burns registered only in satellite images taken within a year or so of the destruction. Any longer than that, and the area would be overgrown with vines and small trees, effectively fooling Landsat—which records the spectral signature of vegetation—into thinking it was still lush forest.

Therein lies one of the problems with satellite data. It can't always be trusted, at least not absolutely. For example, current satellite vegetation maps, which show, for example, the boundaries between cropland and forest, are only about 70 percent accurate, estimates Tom Loveland, a remote sensing scientist with the U.S. Geological Survey in Sioux Falls, South Dakota. Loveland was part of a team that pro-



Satellites will never get this good a view of Costa Rica's rainforest, but they come closer every day.



GARY BRAASCH/CORBIS

duced the first high-resolution global vegetation map using data from polar-orbiting weather satellites. Mistakes tend to sneak into the data on a local scale, he says—for example, when different but adjoining types of land cover reflect similar wavelengths and so are misinterpreted as being the same kind of vegetation.

Satellite data can be misleading when, as in the case of the vegetation maps, it tells only part of the truth. The usual remedy is to build a better, more discriminating instrument for the next generation of satellite. But sometimes even the best sensors don't return accurate measurements. Calibration is an ongoing worry, even after launch. "These satellite instruments are like cars and need tune-ups," says Loveland. It isn't a matter of physically fixing the spacecraft—after they're launched most are beyond reach of a repair crew—but making small adjustments to the mathematical equations that convert the amount of radiation received by this or that sensor into ocean surface temperature, or atmospheric carbon dioxide levels, or some other parameter that scientists want to know. "This is a very human-driven process," says Loveland.

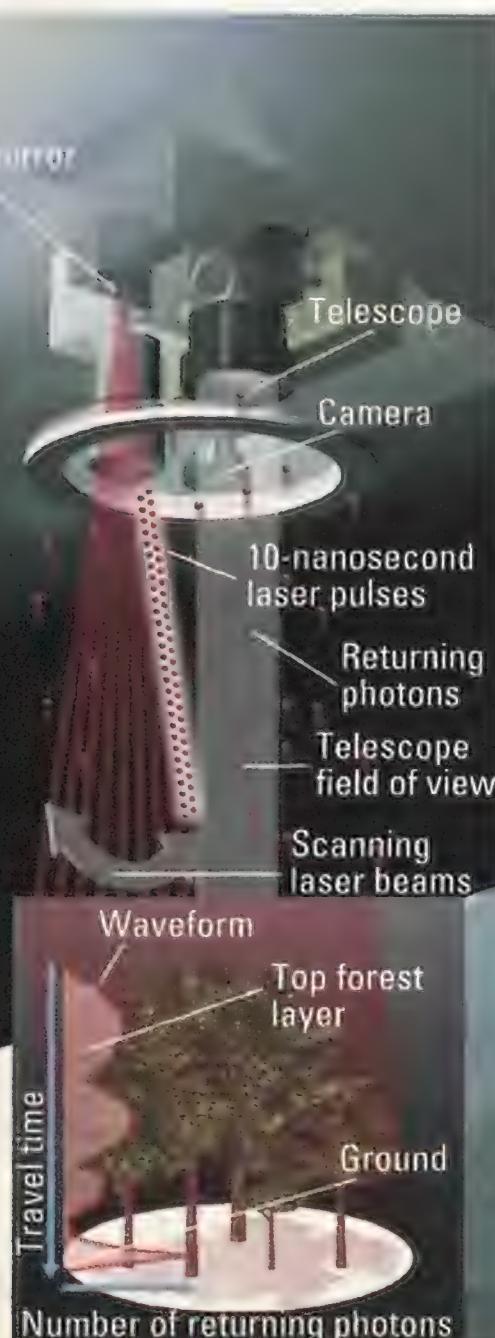
The "ground truthing" of remote sensing satellites has

The Laser Vegetation Imaging Sensor, or LVIS, is an airborne version of the VCL satellite that will measure tree heights from orbit beginning next year. Validation flights over forests from Costa Rica to New Hampshire have shown that the basic concept works.

become a priority for NASA as it launches the \$11 billion Earth Observing System, a fleet of some 20 satellites that will conduct a long-term coordinated study of the planet's land, air, water, and ice. Before any satellite nears the launch pad, its instruments must first survive a lengthy validation process whereby scientists spend months, sometimes years, fine-tuning the sensors in the lab, in the field, and in aircraft overflight tests.

A case in point is the Vegetation Canopy Lidar, due to be launched next year. Essentially an orbiting measuring stick, this low-budget member of the EOS family will measure the height of trees, not just their location. So instead of Landsat's simple, flat map showing green and non-green areas, VCL will produce a three-dimensional view of forested regions. Adding the crucial vertical dimension will enable scientists to measure the total volume of vegetation in a satellite scene for the first time. And because trees store carbon, researchers will have a better understanding of how much carbon stands to be released into the atmosphere if this "biomass" is destroyed.

For the past three years, a team of scientists and engineers from the University of Maryland and NASA's nearby Goddard Space Flight Center has been testing an airborne version of VCL by flying over different types of terrain in a gutted C-130 crammed with electronic equipment. The Laser Vegetation Imaging Sensor, or LVIS (pronounced "Elvis"), works the same way the VCL satellite will—by firing laser pulses at Earth and measuring the time it takes for photons



A Flying Yardstick

LVIS-equipped C-130 at 5 miles altitude.

Combined returns (multiple layers of forest)

LVIS "pings" the ground with laser pulses, then times the return of the photons and counts them (left). The resulting waveform has four peaks showing the four layers from which the laser beam was

1-kilometer-square swath using 40 25-meter-wide footprints

Last laser returns (ground)

Difference between first and last laser returns (canopy height)

JOHN MACNEIL

Field researchers survey tree heights and shapes using hand-held laser range finders. Later, their "ground truth" measurements are compared with readings from the airborne LVIS, whose laser tube pokes down from the belly of a specially equipped C-130 (below).

to bounce back to a detector. The technique, called lidar, is just like radar, except that it uses laser light instead of radio waves. Timing the lidar echo gives the distance to the target, whether it's a high forest canopy, a mid-story stand of trees, or bare ground.

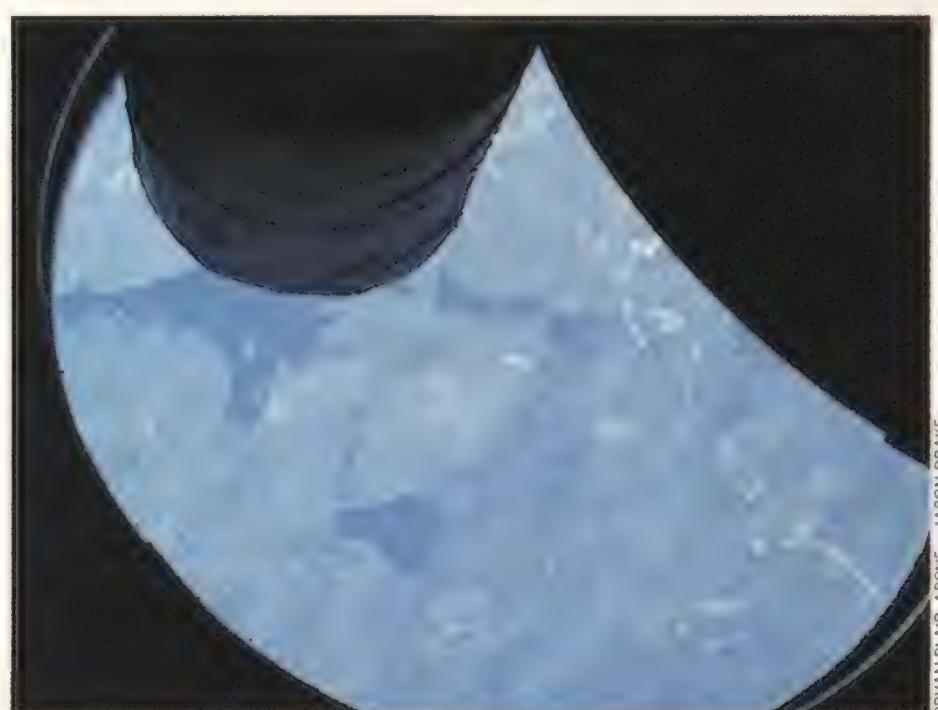
To test LVIS' ability to measure tree heights accurately, its designers have flown the instrument over rainforests in Costa Rica, semi-deciduous woodlands in Panama, and half a dozen ecological research sites in the United States. Then they've compared LVIS' data with ground measurements of the same trees. Last October the team flew over the Sierra Nevada mountains, taking the measure of giant sequoias. Before that, they flew over the deciduous and evergreen forests of the southern Appalachians and the White Mountains of New Hampshire. The advantage of flying over ecological research sites is that they've already been well studied. But the teams on the ground take even more data during the validation campaigns, measuring the heights, crowns, shapes, and radii of the trees so they can be compared to the LVIS data.

Before each trip the team sets up a GPS receiver at the local airfield, which lets the scientists pinpoint the location of each laser "footprint" as the C-130 passes overhead. Once the airplane reaches an altitude of five or six miles, Goddard computer engineer Bryan Blair, LVIS' creator, and David Rabine, a data systems engineer at Science Systems and Applications in Lanham, Maryland (the only two people in the world who can operate the instrument), set their course and begin collecting data. As Blair and Rabine stare at the monitors, the C-130 flies back and forth over the target area, wallpapering the ground with pulses.

On the floor beside them, a large rectangular hole has been cut into the belly of the C-130. Poking through the hole and wedged into thick glass is the laser, the eight-inch telescope that collects the echoed light, and a video camera. As the airplane moves, the laser sends out 300 pulses per second. Each pulse rains photons down on the foliage, and the photons bounce back to the telescope. The first ones back are reflected from the treetops; the last to return are those that have hit the ground.

An onboard computer turns the pattern of reflected photons into a "waveform," which paints a crude silhouette of a particular patch of forest. Forests with a lot of foliage concentrated at the top of the canopy will have a different waveform from those with leaves distributed at various heights (see illustration, opposite page).

LVIS's footprint is only 80 feet wide, but in 10 seconds it can map a swath of forest that measures more than a third of a square mile by using a motor-driven mirror to rapidly redirect the laser beam. The waveforms from all these swaths taken together give a 3-D picture of the forest. "No other instrument can do this," says Ralph Dubayah, a University of Maryland geographer who is the principal investigator



for the VCL mission. "It's a new type of exploration."

The spaceborne version will differ slightly from LVIS because it uses five identical lasers, each pointed at a slightly different angle, to create five footprints spaced more than a mile apart. VCL will cover some 30 million footprints a day, and Dubayah expects that by the end of its two-year mission, the satellite will have returned data for about two to four percent of Earth.

That doesn't sound like much, but statistically it will be enough to let scientists estimate the carbon content of different kinds of forest, says Dubayah. And that information will be useful to countries trading carbon emissions under the international Kyoto treaty approved in 1997. Rather than simply setting hard limits on emissions of carbon dioxide and other greenhouse gases, the Kyoto signatories decided to try a new approach. Polluting countries can buy the right to emit more carbon from countries that haven't reached their emissions limit. And heavily forested nations will earn credits for the atmospheric carbon soaked up by their trees. The general approach has been agreed on, but the exact rules of the new carbon market have yet to be written. "If the policy of global carbon credits is going to work and I'm going to pay Bolivia to keep a tract of forest, then I've got to know how much it's worth—in carbon," says Dubayah.

VCL was not without critics. Many experts were skeptical that the laser could penetrate dense rainforest canopy in regions like the Amazon basin. In Costa Rica, for exam-

ple, only one percent of direct sunlight makes it through the leaves. So the brighter VCL's light, the better chance it has of succeeding. "We need to make sure that the laser has the power to produce enough photons to pass through the one percent opening, hit the ground, and be reflected back to the satellite and produce a clear signal," says Dubayah. The only way to show that the laser could do the job was to build and test it. So far, LVIS has not disappointed: Even in dense rainforest, it can measure tree heights to within about three feet, ground elevation to within four inches, and the location of the footprint to within 20 feet.

Even so, there are bugs yet to be worked out. The LVIS team is still learning how the instrument responds to different kinds of terrain. According to Bob Knox, a forest ecologist at Goddard and a member of the VCL team, cone-shaped and needle leaf trees like red spruce aren't as easy for LVIS to map as broad-leaf trees like sugar maple and beech. Forest density affects the instrument's performance as well. The foothills of the Sierras, which the LVIS scientists use to simulate the African and Australian savannas, have less than 10 percent tree cover, and it's sometimes difficult to get a strong signal in these areas. The tree height measurements also are less accurate on steep slopes.

These, of course, are just the kinds of weaknesses that pre-launch validation is designed to uncover. And with trillion-dollar economic policy decisions riding on the accuracy of environmental data, the ground truthing of satellites—making sure they're calibrated and that they give an accurate picture of conditions on the ground—is more important than ever.

In fact, mismatches between data gathered on the ground and data from satellites sometimes lead to heated political arguments. Early this year a National Academy of Sciences

study panel stepped in to help settle a long-standing dispute between environmentalists and skeptics over whether the planet really is undergoing global warming. For years satellite measurements have shown a smaller temperature rise than have surface measurements, casting doubt on scientists' ability to track climate change. Recently, though, researchers realized that temperature readings from one key instrument—the Microwave Sounding Units flown on U.S. weather satellites since 1979—are sensitive to changes in the satellite's orbit. When orbital drift is taken into account, along with other factors (nearly identical MSUs can have subtle manufacturing differences that affect their output), the puzzling "gap" between space data and ground data mostly goes away. The warming trend seen on the surface is "undoubtedly real," concluded the academy panel.

These are the types of arguments Earth Observing System managers are hoping to forestall. Terra, the flagship of the EOS program, which has been in orbit since December, is in the middle of an extensive post-launch validation campaign. About the size of a schoolbus, Terra is like a flying Swiss army knife. Its five instruments—ASTER, CERES, MISR, MODIS, and MOPITT—will return data on clouds, land use, air quality, and forest burning, among other things.

NASA chose southern Africa to validate Terra in part because it has a rich record of scientific measurements dating back a hundred years or more. Today the region is changing rapidly due to human activities such as deforestation, mining, development, and the air and water pollution that comes with new industry. "You've all these countries getting back on their feet, and clean technology is difficult to implement right now," says Bob Swap, a University of Virginia environmental scientist and the U.S. coordinator of the Southern Africa Regional Science Initiative, or SAFARI 2000—which will help validate the five instruments on Terra.

Southern Africa has other advantages. Research in the early 1990s identified air circulation patterns that influence the whole southern part of the continent. "There is an Afrikaans expression, *potjiekos* (pronounced "poi-KEY-cos"), which means pot food—a stew in which the flavors all blend together," says Swap. "Basically, what you had above southern Africa was a *potjiekos* in which all the industrial and biogenic emissions were swirling around."

SAFARI 2000 caught the attention of southern African scientists because it gave them an opportunity to use remote sensing tools to gain a better understanding of the region. A recent spate of environmental treaties—the Montreal ozone protocol and the Kyoto accords among them—have made developing countries realize that they lack the information necessary to deal with Europe and North America on an equal scientific footing. "They [southern Africans] felt, 'We've got to get our own numbers or someone in the Northern Hemisphere will give them to us,'" says Swap.

During SAFARI 2000, scientists will take measurements on land, in the air, and in space to gauge how forest and savanna burning and industrial and mining activities affect the temperature, climate, and vegetation in southern Africa. The six-week program is planned to begin in August and will involve fieldwork in Namibia, South Africa, Botswana, Zambia, Malawi, and Mozambique.



As part of the SAFARI 2000 campaign, scientists in Botswana set up an observation tower for measuring atmospheric gases and solar radiation. NASA's Terra satellite will return similar data.



One of several aircraft being considered for the SAFARI 2000 regional study is the high-altitude Proteus, built by Burt Rutan's company, Scaled Composites. The Proteus would overfly southern Africa sampling cloud droplets.

While Terra orbits overhead, a high-altitude ER-2, a civilian version of the U-2 spyplane, will act as a mock satellite, flying 12 miles up, above most of the atmosphere. Onboard will be duplicates of all of Terra's instruments. A specially outfitted Convair CV-580 will fly through polluted air taking samples for onboard analysis, while a high-altitude Proteus (a sleek and versatile twin turbofan airplane built by Burt Rutan's company, Scaled Composites) may be used to measure the droplet properties of clouds.

On the ground, scientists from the University of Virginia and NASA's Goddard center are collaborating with researchers in Africa to study vegetation in a 1,000-mile-long strip of land called the Kalahari Transect, which includes a nice variety of terrain types: woodland, grassland, savanna, and tropical forest. The work began in March, during the wet season, when there is a tremendous explosion in plant growth. Vans filled with instruments move from site to site every three days as researchers measure everything from canopy structure to soil moisture to carbon dioxide levels. In planning where to conduct their validation campaign, the researchers also look for large, homogenous areas that the satellite can't miss—like the flat, white Etosha Pan region of northern Namibia—because they are useful calibration targets for air and space data.

The SAFARI 2000 team spent a lot of time in Africa laying the groundwork for these studies. Observation towers with instruments for measuring solar radiation and radiation reflected back up from the ground had to be set up in Mongu, a town in western Zambia, and near Skukuza, inside the Kruger National Park in South Africa. While scouting locations and making contacts with local scientists, Swap had his share of adventure. "In Skukuza we had close calls with hyenas, there were puff adders in our equipment,

scorpions all over the place. One guy got tick-bite fever. And then there's malaria," he says with a chuckle.

As involved as the SAFARI 2000 campaign is, it's only part of the trouble NASA is taking to verify that Terra works as advertised. Validation teams will visit all seven continents and many islands scattered around the world. To ground-truth Terra's volcano data, for example, scientists will venture up to lava flows with a hand-held version of the ASTER instrument. They'll compare notes with other associated research teams sampling the gas from volcanic vents. Anything to check whether the view "up there" reflects what's going on down here.

Still, satellites—even when they work perfectly—tell only part of the story, according to Bruce Miller, a zoologist with the Wildlife Conservation Society working in Belize. "Satellites take beautiful images with excellent pixel definition in which you can count the Cohune palm trees emerging through the rainforest canopy," he says. "But this isn't really telling us what's going on in the forest. There's a new concept called the empty forest, in which the vegetation looks untouched in images, but underneath the forest canopy there are no animals left. They've all been hunted out, or all the frogs are gone due to acid rain and global warming. At one level remote sensing imagery is helping us immensely, and at another level it can provide a false sense of security if it is misinterpreted."

That's why Daniel Nepstad and his team spent so much time on ground studies in Brazil. "There is a tendency among satellite researchers to discount field observations," he says. "If you can't see it on a satellite image then it doesn't exist." But that attitude is changing. And no matter how good satellites get, no matter how much territory they're able to cover at once, "there is little disagreement that ground truthing is the first and last thing you do," says the U.S. Geological Survey's Tom Loveland. Which means that as NASA kicks its remote sensing program into high gear in the next decade, Earth scientists, far from being put out of business, will still have plenty of work to do.



KOREAN WAR ALBUM

The United States had barely recovered from World War II when it was once again called to battle, this time in a faraway land that few Americans could have pointed out on a map. The Korean War wasn't really a war, technically speaking, but a "police action" involving members of the United Nations who voted (with the exception of the Soviets, who walked out) to thwart North Korea's invasion of its southern neighbor. Korea exploded less than five years after the end of World War II, but in the interim, Americans, brimming with optimism, had scrapped their war machine almost as frantically as they had once produced it. It took a long time to put everything back together; it always does.

The combat in Korea had a new edge because both sides fought with the knowledge that nuclear weapons were never out of reach. Korea was also the scene of the first military action across the newly plowed divide between the Communist East and the Western powers. The cold war could turn hot, it was now obvious, as the Truman administration moved to contain the expansion that Communist leaders had promised would one day be global. Too, the nature of warfare was changing: The rules, conventions, and alliances of the past were no longer clear. And in the almost unimaginably cruel winter conditions under which much of the Korean War was fought, even Nature seemed to howl a battle cry at the combatants—like one more enemy.

The Korean War will be remembered in aviation history because it served as the anvil upon which the turbojet-powered airplane was hammered into a fully tempered combat machine. The development started in fighters, but inevitably spread throughout the fleets of both air force and naval air units, as propellers suddenly seemed ancient. The adjustment was especially acute when the

jet met the aircraft carrier, and it seems incredible today that straight-deck carriers would launch and recover jets—but they did. The U.S. Navy learned from that experience, and the next generation of carriers had British-developed decks with runways angled about 10 degrees from the deck's axis, enabling a pilot to take off again if his tailhook missed the wire.

So Korea had several "firsts" in its chronology, as you'll see detailed here. But it had almost no "lasts." Americans and their allies would clash again with Asian Communists in Vietnam in the next decade, and the propeller would still be around for that one too. And—again, technically speaking—Korea is still not over. The current absence of combat is just a long cease-fire, not peace agreed to by treaty.

More than 5.7 million U.S. combatants fought in Korea. Although most Americans know someone who was there, Korean War vets never seemed to get the thanks of a grateful nation that their predecessors got. After it was over, there were no parades. To most people who didn't live through it, the Korean War is an entry in history books, like the war with Spain. If Korea is the forgotten war, as many call it, perhaps a series of anniversary events in the months ahead (see "On the Web Site," p. 91) will help us to remember it. This special section of *Air & Space/Smithsonian* is intended as a start.—*The Editors*

ILLUSTRATION BY DAVID PETERS



The Forgotten Fighter

As the North Korean army rolled south in the summer of 1950, the U.S. Far East Air Force threw everything it had into the air. The Air Force was trying to buy time for the Army's 24th Infantry Division, which was being pummeled into a corner near the coastal city of Pusan. Lockheed's F-80 Shooting Star was called in to do double duty: fight off enemy aircraft and bomb and strafe North Koreans and their artillery near the front lines.

Within two days of action, it was apparent that the new jets could spend only minimal time over target areas. Once they reached Korea from Japan, F-80 pilots had less than five minutes to locate targets and drop their ordnance before having to beat it back to base. General Earle Partridge, 5th Air

Force commander, called up 145 F-51 Mustangs from Air National Guard units to replace the jets in three of his fighter-bomber groups, but he also thought there might be a way to extend the F-80's loiter time. He assigned the problem to the 49th Fighter-Bomber Group, based at Misawa Air Base in Japan. As it happened, two of the 49th's F-80 pilots knew just what to do.

Lieutenants Robert Eckman and Edward "Rabbit" Johnston were among the winners of the Far East Air Force annual gunnery competition in the fall of 1949. They were slated to go to Nellis Air Force Base in Nevada that spring to compete in an all-Air Force event and thought they'd have a better chance at winning with their own F-80s. The only way they'd make the leg from She-

mya Island, Alaska, to Anchorage was to carry more fuel in auxiliary tanks attached to the F-80 wingtips.

"I suggested that we add two additional center sections to the current tanks, which would boost [each tank's] fuel capacity by at least 110 gallons," recalls Johnston today. "The fabrication and assembly was very easy, requiring only the extension of the large bolt that held the three sections of the normal tank together."

"We then flew a series of profile missions and proved beyond a doubt that we had more than doubled the range of the F-80. Unfortunately, this news

Stationed in Japan as air defense fighters when war broke out, F-80s became masters of close air support.



NASM/PHOTOS ON PREVIOUS SPREAD: NATIONAL ARCHIVES

AUGUST 15, 1945

Korea divided into U.S. and Soviet occupation zones along 38th Parallel.

JUNE 21, 1946

FD-1 Phantom becomes first pure jet fighter to launch from and trap on a carrier at sea.

JULY 26, 1947

Truman's National Security Act creates U.S. Department of Defense.

OCTOBER 1, 1947

F-86 Sabre prototype undergoes first flight test.

DECEMBER 30, 1947

MiG-15 prototype begins flight tests.

reached HQ U.S. Air Force and the engineers of Air Force Materiel Command. This created a great uproar about unauthorized modifications and 'backyard engineering.'

The Air Materiel Command, fearing the heavier tanks would stress the wings, vetoed the modification. But in the desperate days of June 1950, General Partridge overrode the veto and ordered the Materiel Command to fabricate the big Misawa tanks and equip all F-80s with them.

"You had to be careful when you started pulling Gs in strafing and dive bombing," recalls Johnston. "I knew of quite a few pilots who pulled too hard. It would tear the shackle [that held the tank on] out of the wing. Suddenly there was this great demand for shackles."

At least one pilot ran into a serious problem when one tank failed to feed and he couldn't jettison it. Landing an F-80 with 265 gallons of jet fuel hanging on one wing was a dicey proposition. "He wrapped up the airplane," says Johnston, but survived the crash.

"I ran a test mission to see if that condition couldn't be corrected by shooting holes in [the tank] with a .45-caliber service automatic from the cockpit [so the fuel would leak out]," says Johnston. "This was General Partridge's idea—not mine! It worked fine."

With the F-80's new extended range, its pilots were able to hone their tactics in air-to-ground attack. The ill-equipped North Korean air force had been vanquished, freeing the F-80 from most of its dogfighting duties. Then the Marines landed at Inchon, behind the North Korean forces, and triggered their rapid retreat. On September 28, the 49th Group began flying out of Taegu Air Base, marking the first time the jets operated from Korea. Now they could strap on a variety of heavy ordnance and still reach the areas around the main line of resistance.

Lieutenant Colonel Clure Smith, com-



Should've seen the other guy: Al Coleman and his F-80 (top) after a typical ground attack run. Before it was "tanked" for bombing (above), this F-80 won a fight with an Il-10.

manding officer of the 25th Squadron, remembers "load configurations that we used, that would make the Lockheed design engineers shake their heads in disbelief. On some missions, we would taxi out with two 265-gallon tip tanks, two 1,000-pound bombs, and four five-inch rockets and not enough power to get off the runway." To address this problem, crews mounted two jet-assisted-takeoff bottles on the fuselage. "You would be at full power with the end of the runway coming up fast and hit the JATO," says Smith. "All you could do is pray that they would provide the speed that you had to have because if they failed to activate, we were in a lot of trouble."

On many missions, the trouble didn't end once the runway was cleared. As with most attack bombers, the F-80s were vulnerable to anti-aircraft fire—

some of it their own. Johnston remembers one mission in particular: "I turned loose four rockets a little too close, and dirt, mud, and debris from the blast knocked several holes in the bottom of the aircraft."

Crew chiefs can tell you about the punishment the F-80 absorbed during missions against heavily defended targets. John Nossick, a senior crew chief with the 51st Fighter Wing, is still impressed by the F-80. "Lockheed had designed such a great airplane that it seemed all we had to do was fill the tanks, arm it, and send it back on its way," he says. "Many of our F-80s were so busy that they never had the 25-hour and 50-hour maintenance done. We flew them for 100 hours, then sent them back to Japan for the 100-hour inspection and to patch up all the holes."

"Some of these aircraft hit cables that the communists had strung out across the valleys, cutting the vertical stabilizers off, and in some cases the tips of the wings were sheared off. Triple-A [anti-aircraft artillery] put a lot of holes in the fuselage and wings, but with some good strong tape they were ready to be reloaded and sent back into the fight."

As newer jets became available, fewer units flew the F-80. The 49th transitioned to Republic's F-84 Thunderjet, the last of the straight-wing fighter-bombers. Other wings began flying the North American F-86 Sabre, which had been rushed into service in December 1950 to counter the swept-wing, supersonic MiG-15, a jet that easily outclassed the F-80. The famous 80th "Head Hunters" Squadron was the last to fly the F-80 as a fighter-bomber in Korea.

Although the F-86 is easily the most famous of the Korean War fighters, the F-80 is still respectfully remembered at least by its pilots and undoubtedly by some of those 24th Infantry soldiers, who held on at Pusan thanks in part to the Shooting Star.

—Warren E. Thompson

MAY 5, 1948

Flying Phantoms, the Navy's first jet fighter squadron becomes carrier-qualified.

AUGUST 15, 1948

After supervised elections, U.S. military government turns over power to Republic of Korea.

JUNE 25, 1950

North Korean People's Army invades South Korea; United Nations calls for an end of aggression.

JUNE 27, 1950

U.N. asks member countries to aid Republic of Korea; U.S. announces intervention.

JUNE 27, 1950

North Korean Yaks attack Seoul airfield; F-82s and F-80s dominate in tangle with Yaks and Illyushins.

The Heroes

For Jesse Brown, the greatest challenge was not the rigors of becoming a Navy fighter pilot, nor the dangers of flying missions against North Korea from the pitching deck of an aircraft carrier. Brown rose from Jim Crow-era Mississippi to the cockpit of an F4U Corsair when the services were still segregated, becoming the first African-American to complete Navy pilot training. In 1948, he began a tour of duty with VF-32 at Quonset Point, Rhode Island.

About a year later, Brown met a new pilot named Thomas J. Hudner, a graduate of Phillip's Academy in Andover, Massachusetts, and the United States Naval Academy in Annapolis, Maryland, and also the son of successful Massachusetts business owners. After graduation from the academy in 1946, Hudner served aboard a cruiser as a

signal officer before being assigned to shore duty in Pearl Harbor. Bored with his job, he applied for flight training at Pensacola.

After earning his wings, Hudner was eventually sent to VF-32, which had earned a notoriety for being the home of the Navy's only black pilot. Brown and Hudner were soon flying together. Despite Lieutenant (Junior Grade) Hudner's senior rank, Navy policy set flying assignments based on experience, and Ensign Brown had more hours. Hudner was assigned to be Brown's wingman and found Brown a patient and disciplined pilot.

But off duty, the two aviators spent little time together. "In those days, the O (officers') club was the center of activity," Hudner says, who recently retired as the Massachusetts commissioner of veterans' affairs. "He [Brown]

was married and I was a bachelor. [Almost all the bachelors] went to the club because the club was the only place to gather. Jesse didn't go very much—very few of the married officers went there, because they went home to their families at night."

In June 1950, VF-32 was operating from the USS *Leyte* in the Mediterranean on a routine cruise but was soon diverted to the Korean peninsula when North Korea invaded South Korea. On December 4, both pilots were part of a formation of eight Corsairs flying armed reconnaissance patrols near the Chosin Reservoir. "We'd fly around and look for targets of opportunity," Hudner says. "We didn't have predesignated targets, but if we saw military equipment, trucks, or troops, we'd destroy them with rockets or our .50-caliber guns. We were high enough to see fairly well ahead, but low enough to see objects and people on the ground. It was very mountainous in that area and we didn't want to go too low. A lot of our planes came back to the ship with small-caliber holes in the wings and fuselage."

Hudner and Brown were at about 1,000 feet when Brown radioed that he was losing oil pressure. "We think it was an oil line that got hit—somebody just got a lucky shot," Hudner says.

The engine on Brown's Corsair quit. Too low to either clear the mountains or bail out, Brown was forced to attempt a wheels-up landing in the best place he could find—a clearing that looked reasonably flat.

Brown had limited control over his



Jesse Brown (left) was the Navy's first African-American pilot. Thomas Hudner was awarded a Medal of Honor (opposite) for trying to rescue Brown after he was shot down near the Chosin Reservoir.

JUNE 28, 1950

B-26s attack troops in Han River area. North Korean army captures Seoul.

JUNE 30, 1950

President Truman orders ground forces into Korea and authorizes Air Force to bomb North Korea.

JULY 3, 1950

USS *Valley Forge* and HMS *Triumph* launch air strikes in and around P'yongyang.

JULY 5, 1950

Near Osan, Task Force Smith troops fight for the first time, suffering heavy casualties.

JULY 18, 1950

U.S. Cavalry lands at Pohangdong; U.S. aircraft destroy key oil refinery in Wonsan.



NATIONAL ARCHIVES

unpowered Corsair, and when it slammed into the ground, it bent 30 degrees at the cockpit. The F4U slid through snow and finally came to rest as smoke began to rise from its engine. Hudner and his fellow pilots circled the wreck. "The plane was so mangled from the landing that we thought he had died in the crash," Hudner says. "We continued to circle around and the conversation on the radio was 'My God, poor Jesse.' I knew that his canopy was open because I went over the checklists with him, but the airplane hit with such force that the canopy slammed shut. Then someone noticed that his canopy was open and he was waving to us."

Seeing that Brown was alive, the flight leader climbed to altitude to give his radio better range, transmitted a Mayday, and asked for a rescue helicopter. "We got an acknowledgment that the helicopter was on the way, but it was at least 15 minutes before it could get there," Hudner says. The delay, Brown's apparent inability to free himself, and the smoke rising from the Corsair made the situation desperate. "I made the decision to try and pull him out of the cockpit and both of us would fly out with the helicopter," Hudner says.

Hudner made a low pass to examine the clearing. He lowered his flaps and tailhook and landed the Corsair on its belly. "I hit a lot harder than I thought I would," Hudner says. "We were at 6,000 feet above sea level so the true airspeed was a lot faster than the indicated airspeed. All that was going through my mind was 'What in the hell am I doing here?'" After his aircraft lurched to a halt, Hudner unstrapped and raced across the snow to Brown's F4U.

Brown was calm and had no visible injuries but his fingers were already partially frostbitten in the frigid air. Hudner saw why Brown hadn't been able to escape—one of his legs was pinned between the instrument panel and the wall of the cockpit. "He was conscious when I first got there, but he said very little," Hudner says. "He was calm and serene."

Hudner realized he couldn't free Brown by himself. After returning to his own Corsair and radioing to the rescue helicopter to bring an ax and fire extinguisher, Hudner ran back to Brown and scooped snow into the F4U's cowling to try to extinguish the fire.

When the rescue helicopter arrived,

Captain **John A. Walmsley**, who was killed in September 1951 while directing the searchlight from his disabled Douglas A-26 toward an ammunition train so his wingman could continue the attack; Major **George A. Davis Jr.**, who died in February 1952 when he and his wingman—outnumbered 12 to two—attacked a MiG formation to protect a force of fighter-bombers; and **Charles J. Loring**, who intentionally crashed his damaged F-80 into a North Korean gun emplacement.

Hudner got the ax and swung it at the Corsair's fuselage, but it only bounced off. Hudner jammed the fire extinguisher into the engine cowling and discharged it.

Hudner and helicopter pilot Charlie Ward continued to try to free Brown, but the situation was becoming hopeless. With darkness descending and the already frigid temperature dropping near -35 degrees Fahrenheit, the two men could not stay much longer. Ward's Sikorsky HO3S helicopter had no instruments to fly at night, much less through mountainous terrain. Hudner spoke softly to Brown, telling him that they'd have to leave. Brown, whose eyes were closed, did not respond. Hudner didn't know if he was still alive, but little else could be done to help his squadron mate.

On April 13, 1951, President Harry Truman presented Hudner with the Medal of Honor in a simple ceremony that included Daisy Brown, Jesse Brown's widow. Despite their different backgrounds, Hudner and Brown had been drawn together by a simple, but powerful brotherhood—a bond graced by a singular and courageous act.

—John Sotham

JULY 22, 1950

First helicopters, H-5As, arrive at Taegu with 3rd Air Rescue Squadron.

JULY 22, 1950

Battle for Taejon ends with heavy U.S. losses and retreat.

JULY 23, 1950

5th Air Force trades range-deficient jets for 145 F-51s.

AUGUST 3, 1950

Navy HO3S helicopters enter combat service, supporting Marines in Changwon.

AUGUST 4, 1950

Pusan perimeter established in southeastern Korea.

Breakout from Chosin

It took a “bridge from the sky” to span the missing 20 feet on the U.S. forces’ escape route.

First Lieutenant Ted Momchilovich hauled back on the yoke of his Fairchild C-119 Flying Boxcar, and the lumbering transport lifted off the runway at Yon-po, a United Nations-controlled airfield on the southeastern coast of North Korea. He gave the thumbs-up signal to his copilot, Second Lieutenant Irving Richardson, and called, “Gear up!”

It was cold and loud inside the C-119. With the huge aft clamshell doors removed for this cargo drop, arctic air howled into the cargo bay. On the ground it had been 25 degrees below zero, and as the airplane climbed it got even colder. Richardson tucked an old Army blanket around his legs.

On this morning—December 7, 1950—seven other C-119s of the Air Force’s 314th Troop Carrier Group were making the same half-hour flight. Their mission: an airdrop over a U.S. outpost that was encircled by Chinese troops in the desolate Taebek Mountains of North Korea, about 14 miles south of a hydroelectric complex the U.N. forces called the Chosin Reservoir.



NATIONAL ARCHIVES/USAF COLLECTION

Air support was of paramount importance in Korea’s rugged terrain, whether it took the form of a delivery of a 105-mm howitzer from an Air Force C-119 (above) or an air strike by a Marine F4U Corsair (opposite).

Soon after China entered the war, Chinese troops blew a gap in a concrete span across a deep gorge three miles south of the village of Koto-ri, effectively blocking the withdrawal of 10,000 Marines, 2,400 U.S. Army troops, and 1,000 vehicles from Chosin. As many as six divisions of the Chinese army—120,000 men—were closing in.

The 314th’s mission this morning called for each of the C-119s to air-drop a single span of a steel M-2 treadway bridge. Normally the bridge sections would have been transported by truck. But the Chinese were everywhere, and an air drop was the only way to get the bridge to the withdrawing friendlies. There was only one problem: Though it had been attempted once, nobody had ever successfully air-dropped an M-2 bridge before.

Two days earlier, crews of the 314th, concerned about the massive cargo they were about to handle, had performed a quick and dirty test drop. They had rigged six personnel chutes to one of the 2,500-pound, 16-by-five-foot spans, took it aloft on a C-119, and

AUGUST 5, 1950

Carrier aircraft attack communication lines and begin close support missions.

AUGUST 13, 1950

First U.N. counterattack collapses.

AUGUST 15, 1950

Four-day battle of “the Bowling Alley”; U.N. forces hold back North Korean offensive.

SEPTEMBER 15, 1950

Inchon landings of U.N. forces; Navy squadrons fly air support.

SEPTEMBER 16, 1950

After three weeks of heavy fighting, U.N. forces begin breakout of Pusan Perimeter.

shoved it out the back end. The six canopies opened but became hopelessly entangled. The span plummeted to the ground and was destroyed on impact.

Captain Cecil Hospelhorn, commander of the 2348th Quartermaster Airborne Air Supply and Packaging Company, and Major Jesse Perry of the 314th Troop Carrier Group analyzed the failure. Their conclusion: The risk of entanglement might be reduced if two 48-foot-diameter G-5 parachutes were attached to each end of the span in place of the six 24-foot chutes. But they weren't certain, and there was neither the time nor the bridge parts to spare for another test. The next drop would have to be for real.

The conditions U.S. soldiers faced in the winter of 1950 at the battle of the Chosin Reservoir were unlike any encountered in U.S. combat history. The troops had to overcome a seemingly unstoppable enemy, terrain like the surface of Mars, and a misguided military strategy that had gotten them into this fix in the first place.

In October 1950, after a successful landing at Inchon and the recapture of Seoul, General Douglas MacArthur ordered U.N. troops to pursue the retreating North Koreans north to the Yalu River, the physical and political boundary between Korea and Manchuria. MacArthur predicted the war would be over by December and the troops home by Christmas.

The question of whether China would come to the aid of the retreating North Korean People's Army was unanswered. Despite significant clashes with Chinese troops in late October, MacArthur didn't believe the Chinese would enter the fracas in force. He was wrong.

In November 1950, the Chinese attacked from the northwest, striking a double blow: to South Korean forces and to the U.S. Eighth Army. Meanwhile, Chinese forces crossed the Yalu



at Manpojin, decimating the U.S. Seventh Infantry Division on the east side of the Chosin Reservoir. At Yudam-ni, on the water's western edge, Chinese troops surrounded and cut off the Fifth and Seventh Marines from the rest of their division, which was strung out over a 35-mile stretch of road.

Back home, the press reported the carnage: "America's worst military licking since the Battle of the Bulge and maybe even Pearl Harbor," *Newsweek* opined. "The worst defeat the United States ever suffered," said *Time*. Clearly, it was time to regroup.

The breakout plan called for the trapped Marines to withdraw south along a narrow, winding supply road to the port of Hungnam, where a Navy fleet was waiting to evacuate the entire force. Responding to someone's question about the retreat, Major General O.P. Smith, the First Marine Division's commander, put his spin on the situation: "No, not a retreat," he lectured. "It will be an attack in another direction."

Almost the moment he said them, his exact words were garbled and then immortalized. Newspaper headlines screamed: "Retreat? Hell, no! We're attacking in reverse!" Whatever Smith said, his words became a rallying cry for the entrapped forces. To get to the coast, they were going to have to march 78 miles along an icy mountain road lined with hostile forces and cross a bridge that wasn't there.

The C model of the C-119 was just coming off the Fairchild production lines at Hagerstown, Maryland, when the war started. The ungainly airlifter, with its horizontal stabilizer linking two elongated tail booms, could take off at a gross weight of 74,000 pounds, almost double its own empty weight of 37,691 pounds. Twin 3,500-horsepower Pratt & Whitney R-4360-20WA engines powered the beast, which could attain a speed of 281 mph at 18,000 feet. With its aft doors removed, nothing in the Air Force was better suited for air-dropping bulky loads.

SEPTEMBER 17, 1950

U.N. troops capture Kimpo airfield.

SEPTEMBER 29, 1950

U.N. troops complete recapture of Seoul.

OCTOBER 7, 1950

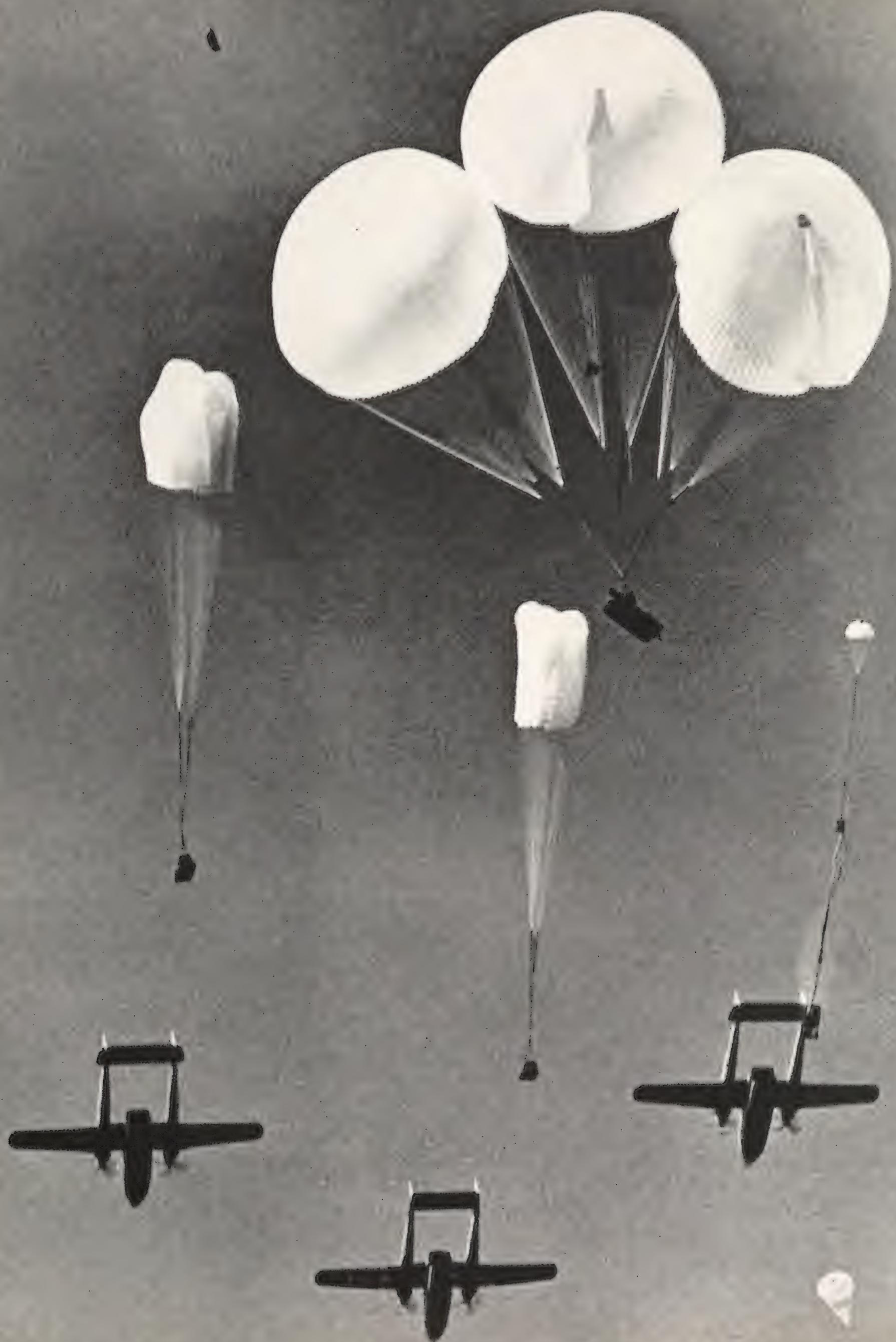
U.N. forces cross 38th Parallel; U.N. sanctions defeat of North Korea and attempted reunification.

OCTOBER 14, 1950

Chinese Communist troops cross Yalu River into Korea.

OCTOBER 19, 1950

U.N. captures P'yongyang, the North Korean capital.



Removable aft doors enabled C-119s to drop bulky equipment readily (opposite). C-119s dropped an M-2 bridge so U.N. forces could span a gorge next to this gatehouse (right).

In August 1950, members of the 314th Troop Carrier Group, stationed at Stewart Air Force Base in Tennessee, picked up 100 of the new craft. The C-119C was so new that sections of its technical manuals were printed in red, indicating that engineers weren't sure how the aircraft would respond under certain conditions. Accurate weight and balance data had yet to be published, so loading had to be determined through trial and error.

First Lieutenant Jack Robbins, operations officer for the 314th, tested one C-119 over Ashiya, Japan, headquarters of Far East Air Force's Combat Cargo Command. To determine how well his Flying Boxcar would do with an engine out, he loaded it with 55-gallon drums of water, took off, and at around 5,000 feet, shut down the right engine. After some tests, Robbins tried to restart the dead engine, but the propeller would not rotate. Robbins' crew chief averted disaster by hacking holes in the metal drums with an axe so the water could run out, and they landed unscathed.

Several miles north of Yonpo, the Taebek Range rose to meet Momchilovich's C-119. The ground below was a lumpy carpet of snow-covered hills, and co-pilot Richardson could see enemy fox holes in the hills along the main road and plumes of smoke from burning vehicles. As they approached Koto-ri, Momchilovich alerted the "kicker," a crew member who pushed out the cargo—or hesitant paratroopers. "Six-minute red light!" he announced over the PA system. A dull red light flashed in the cargo bay.

Robbins and Perry, the two officers who had argued for two big chutes



NATIONAL ARCHIVES/USAF COLLECTION (3)

in place of six little ones, had also advised the kickers to untie the bridge spans once airborne, move them back so that seven feet of span extended outside the airplane, and tie them off again until drop time. Hospelhorn thought that this technique would cut ejection time from four seconds to less than two.

Army riggers had worked through the night packing each metal span and its wooden supports on a plywood pallet; each package weighed two tons. Four bridge sections were all the two Brockway bridging trucks could carry, but Lieutenant Colonel John Partridge, commanding officer of the First Engineer Battalion, requested eight just in case something went wrong.

Robbins was confident: "We had dropped everything you can think of: ammunition, food, medical supplies, Army jeeps, trucks, big guns that weighed fifteen, sixteen thousand pounds," he recalls today. "There was no doubt in my mind that if it could be rigged to



Troops at the gatehouse inspect the damaged hydroelectric complex near Koto-ri (above). Chinese units blew up the bridge here, blocking the route from Chosin to the coast.

NOVEMBER 1, 1950

Chinese attack in force near Unsan; first appearance of MiG-15.

NOVEMBER 8, 1950

First jet vs. jet kill: F-80 downs MiG-15; First appearance of F-86 Sabre.

NOVEMBER 24, 1950

Gen. Douglas MacArthur's final "Home by Christmas" offensive begins.

DECEMBER 11, 1950

End of Chinese strike against marine and army divisions at Chosin Reservoir; marines retreat.

JANUARY 4, 1951

Seoul captured by Chinese.

float fairly evenly, we could drop it."

Over Koto-ri, Momchilovich descended to 800 feet, reduced power, and slowed to 140 mph. He felt the pull on the yoke as the C-119 got nose-heavy, so he added nose-up trim. At low altitude, they were vulnerable to enemy fire, and Momchilovich and Richardson had flak jackets stowed beneath their seats for protection. "Green light!" the pilot called, cobbing the throttles.

A loud bell rang, the -119's nose lurched up, and the kicker cut the load loose. The wooden pallet, moving aft on metal rollers in the cargo bay floor, rumbled out the back end. Static lines attached to the aircraft opened the chutes. On the ground, a weary Second Lieutenant Roy Ducham looked up to see the bridges descending a quarter of a mile away. "They looked like howitzers falling," he recalls. "The chutes were enormous."

By noon, all eight of the C-119s had dropped their loads. Six of the eight bridge sections landed successfully.

One was damaged beyond repair when one of its chutes didn't open. Another fell outside the drop zone behind enemy lines. The surviving sections were turned over to First Lieutenant Charles Ward of the 58th Treadway Bridge Company. Now it was just a matter of transporting the precious cargo down a tortuous mountain road.

While the freezing American troops consolidated first at Hagaru and then at Koto-ri, Marine and Army engineers carved two airstrips just long enough for twin-engine C-47s to land and evacuate the wounded. First Lieutenant George Babe, who worked on the runway at Koto-ri, recalls: "We selected a site to the north, half of which extended beyond our lines. It looked like an old cornfield; you can't really call it an airstrip. The ground was frozen so hard we merely knocked the tops off the furrows."

Babe described how engineers used coal ash from a nearby railroad depot

to fill a stream bed that paralleled the runway and thus produce a wider berth for the airplanes. The airstrip was approximately 1,500 feet long and 50 feet wide when the work was abandoned. At Hagaru, the strip was twice as long but just as unforgiving. In early December, more than 4,600 sick and wounded were evacuated in 240 sorties, most flown by the 21st Troop Carrier Squadron.

Captain Paul Fritz flew 25 missions into Hagaru and Koto-ri; he remembers: "[On the approach], we had to practically roll our wheels on the top of a slag pile, then chop the power, dive for the end of the runway, recover, get into a proper landing attitude, and then settle down and get her stopped on packed snow. It was a cheap thrill every time."

Six pilots of Greece's Royal Hellenic Air Force flew supply missions with the 21st. When asked his opinion of the runway at Hagaru, one pilot told reporters: "A bad airstrip? Hah! You should see some of the airstrips in Greece."

As the C-47s arrived with supplies and departed with wounded, an endless air train of C-119s rained crates of food, ammunition, fuel, and warm clothing over the trapped soldiers. In just 10 days, the 314th dropped more than 1,200 tons of supplies over the Chosin Reservoir.

Encouraged by the success of his air operations, Combat Cargo Command's leader, Major General William Tunner, a mastermind of the Berlin Airlift, flew into Hagaru on December 5 to propose the wholesale air evacuation of Marine and Army troops. But according to one account, General Smith refused, saying, "No, we walked in here and we're



NATIONAL ARCHIVES/USAF COLLECTION (2)

When the pallets departed, static lines, clipped to a cable in the cargo hold (left), pulled the parachutes open. Rollers in the floor enabled the crew to shove the load out...

JANUARY 25, 1951

U.N. forces reassume offensive.

FEBRUARY 11, 1951

Chinese counter-offensive begins north of Hoengsong.

MARCH 1, 1951

U.N. line reaches between the 37th and 38th Parallels.

MARCH 2, 1951

30-day bombing campaign against railroad bridges in "Carlson's Canyon" begins.

MARCH 18, 1951

U.N. forces retake Seoul.



going to walk out." Instead, he asked Tunner to continue the airdrops and to evacuate as many wounded as possible. The First Marine Division, Smith said, intended to fight its way out.

It was snowing hard on December 8 as Charles Ward, accompanied by Marine First Lieutenant Ozzie Vom Orde and his First Platoon, D Company, departed the Koto-ri perimeter at 2 p.m. with their bridge. Marine and Navy air support, which had proven so effective, was grounded. Held up by incessant Chinese small arms and mortar fire, Ward was finally ordered back to the perimeter.

Vom Orde then made a mistake that haunts him to this day: While helping one of the bridging trucks negotiate the narrow road, he told the driver to back into a clearing, not realizing it was a frozen lake. The rear wheels of the truck cracked through the ice and began to sink. Quickly, a Marine chained the truck to a tank, which pulled it to

...so that the pallets dropped in a tight formation (above). It took only seconds to loose a full load, and precise timing paid off with an accurate drop in a U.N. zone.

safety. "That made my heart beat a little bit," says Vom Orde. "It's funny now, but it wasn't then."

Clear weather on December 9 allowed air support to resume its mission, and more than 300 sorties were flown that day. "The air support was magnificent," recalls George Babe. "We would have had a much harder time of it without them."

At about 1 p.m., the rigs reached the bridge site. Here, Vom Orde and First Lieutenant Dave "Pep" Peppin of D Company's Third Platoon surveyed the scene. The concrete apron bridge appeared to span about 70 to 80 feet; the blown gap, maybe 16 to 20 feet. There was a concrete gatehouse on one side from which four giant water pipes ran—a hydroelectric complex of which the

bridge was a part. Beneath the gap was a 1,500-foot-deep gorge.

The M-2 treadway bridge itself consisted of two heavy channel sections in which vehicle wheels rolled as they crossed. Troops marched across on a four-inch-thick plywood section laid on top of steel spreader bars that maintained the space between the wheel channels. Using a length of communications wire, the team measured the breach. "Oh my God," Vom Orde said; the bridge spans were about five feet too short.

Thinking quickly, Vom Orde outlined a plan to build a wooden abutment on a small ledge about five feet below the road surface on the far side of the gap. The bridge could be laid on top of the abutment. With the help of Chinese prisoners of war, who carried sandbags used to steady the makeshift structure, the engineers finished the job in three hours.

Between December 11 and December 24, the Navy evacuated 105,000 troops, 91,000 refugees, 350,000 tons of cargo, and 17,500 vehicles before demolition teams obliterated the port city at Hungnam. They wouldn't be home by Christmas, but at least they were alive.

For their roles, the 314th Troop Carrier Group, 21st Troop Carrier Squadron, and 801st Medical Air Evacuation Squadron were awarded Distinguished Unit Citations. (The Greek unit was awarded a Presidential Unit Citation). *Time* featured the "bridge from the sky" and a picture of "William Tunner, Airlifter," on its cover.

For Jack Robbins, it was nearly 50 years before he met any of the 10,000 Marines who survived the ordeal at the reservoir. In 1999, while addressing members of the Chosin Few veterans' organization, Robbins asked those present to raise their hands if they had crossed the bridge. Nearly every man in the room put his hand up.

—Joe Sugarman

APRIL 2, 1951

First Navy bomb-loaded jet strike, using F9F Panthers, leaves Princeton carrier.

APRIL 10, 1951

Nine A-bombs released from AEC to USAF, later deployed to Guam with 9th Bomb Group.

APRIL 11, 1951

MacArthur recalled; General Matthew Ridgway given command.

APRIL 17, 1951

Rangers and aircraft specialists helicopter into enemy territory to recover a downed MiG.

APRIL 30, 1951

Successful Hwachon Dam raid, the only torpedo attack of the conflict.

The Aircraft



Gloster Meteor

Flown by the Royal Australian Air Force, the Mk. 7 and 8 versions of Britain's first operational jet excelled at ground support and escorted B-29s with F-84 Thunderjets, but were badly outclassed by MiGs.



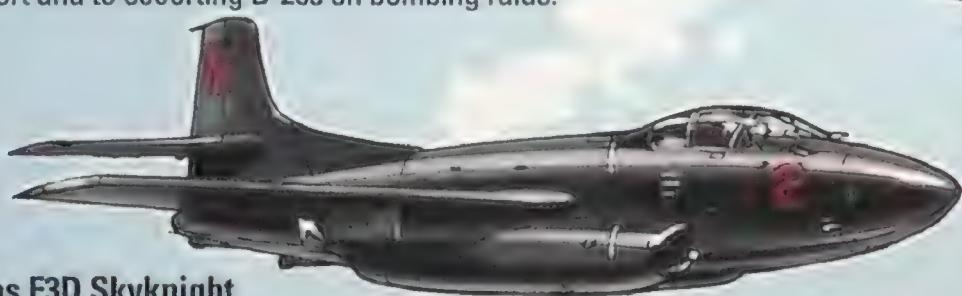
Lockheed F-94 Starfire

An afterburner-equipped development of Lockheed's T-33 trainer, the Starfire, the U.S. Air Force's latest all-weather fighter, flew long-range night escort for B-29s.



Lockheed F-80 Shooting Star

The U.S. Air Force's first operational jet fighter won the first jet dogfight when it brought down a MiG-15 in November 1950. After the F-86 arrived, the F-80 was relegated to close air support and to escorting B-29s on bombing raids.



Douglas F3D Skyknight

The Skyknight provided long-range night escort for B-29s. Carrier deck crews had no affection for the F3D: Its canted tailpipes scorched and sometimes set fire to the teak decks and made deck plating red-hot.



Mikoyan MiG-15

With a top speed near Mach 1, the MiG-15 was 100 mph faster than an F-80C, and central fire control systems on B-29s had trouble tracking it. But in general its pilots were easily outflown when the F-86 arrived: They routinely stalled and entered an unrecoverable spin, they often executed no evasive maneuvering when attacked, and sometimes they even bailed out before being shot at.

Vought F4U Corsair

Though its oil cooler made it vulnerable to shrapnel and small arms fire, the Corsair was a superb bomber, night fighter, and ground attack aircraft.



Ilyushin Il-10 Shturmovik

The latest version of World War II's Il-2 "flying tank," the Shturmovik was considered the finest assault and anti-tank aircraft of its time.



Fairchild C-119 Flying Boxcar

The Boxcar carried paratroops and cargo and, in December 1952, seven tons of fresh fruit for frontline units for Christmas. The transport would often fly in a load of supplies and return to Japan with a load of medevac patients.



McDonnell F2H Banshee

The flak-resistant, easy-to-maintain, carrier-based "Banjo" fighter-bomber flew ground support, performed photo reconnaissance, and escorted B-29s.



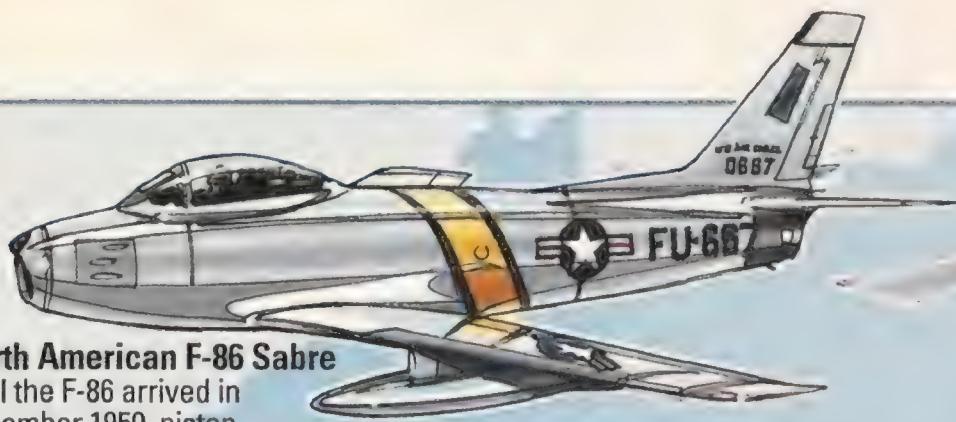
North American F-82 Twin Mustang

The F-82 initially flew daylight cover for the evacuation of civilians from Korea. The fighter-bomber and night interceptor could loiter over evacuation ports much longer than fuel-guzzling F-80s.



Polikarpov Po-2

The "Bedcheck Charlie" nocturnal air raider, along with Yak-11s and -18s, tossed grenades and light bombs over airfields and supply dumps. Too slow and maneuverable for a jet to hit, they were vanquished by night-fighting Corsairs, which deployed full flaps and landing gear to slow down to 90 mph.



North American F-86 Sabre

Until the F-86 arrived in November 1950, piston aircraft got better results than jets. The Sabre had a slower rate of climb than the MiG-15 but could outrun it in a dive. Later models had hydraulically boosted ailerons for faster roll response and a "flying tail," a horizontal stabilizer that moved as a unit for better maneuverability.



Bell H-13

The U.S. Army's MASH medevac version of the Bell 47 carried two stretchers in litters attached to the landing gear skids.



Republic F-84 Thunderjet

The F-84 fighter-bomber arrived in late 1950 to bolster daylight ground attack capability, flying into MiG Alley with F-86s as top cover. When loaded with bombs and operating from shorter airstrips, the F-84 often required a jet-assisted takeoff.

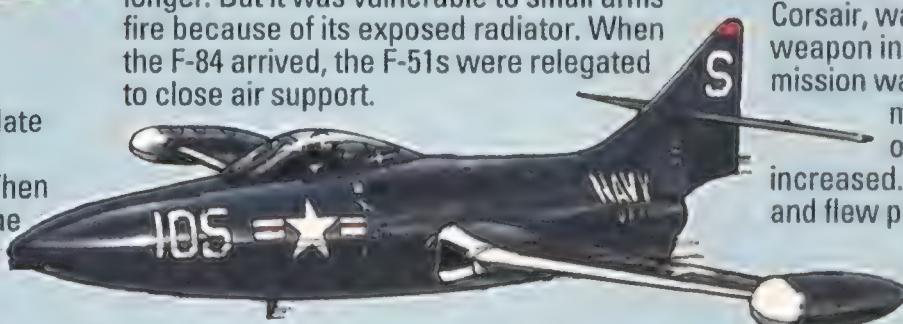
North American F-51 Mustang

The F-51 was in some ways superior to the F-80: It had a longer range, used less fuel, carried more ordnance, and could loiter longer. But it was vulnerable to small arms fire because of its exposed radiator. When the F-84 arrived, the F-51s were relegated to close air support.



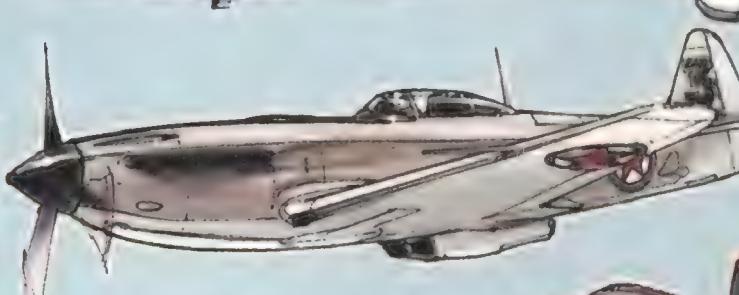
Grumman F9F Panther

The Panther, teamed with the Corsair, was the Navy's principal air weapon in Korea. The F9F's primary mission was as a bomber: When it moved to land bases its ordnance load was greatly increased. It was also a night fighter and flew photo reconnaissance.



Hawker Sea Fury

Great Britain's Sea Fury operated as a fighter/bomber/ground attack carrier aircraft, along with Supermarine Seafires (the carrier version of the Spitfire) and Fairey Fireflies.



Yakovlev Yak-9

The North Korean air force's fighter regiment comprised Yak-3s, -7s, and -9s, which went after everything from ground troops to F-80s to B-29s.



Douglas B-26 Invader

The U.S. Air Force's primary light bomber while the B-47 was under development, the Invader prowled for trucks, tanks, and trains with great success even at night, thanks to flares dropped by C-47 "Fireflies."



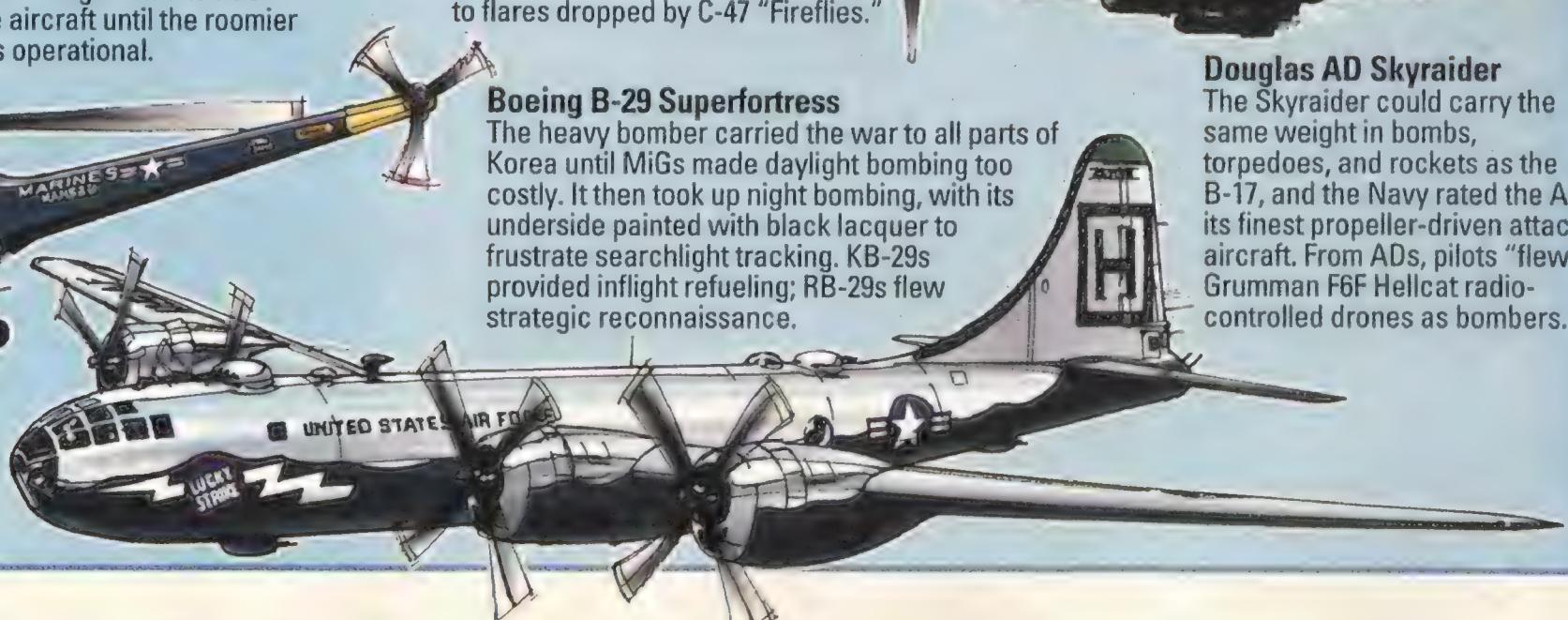
Douglas AD Skyraider

The Skyraider could carry the same weight in bombs, torpedoes, and rockets as the B-17, and the Navy rated the AD its finest propeller-driven attack aircraft. From ADs, pilots "flew" Grumman F6F Hellcat radio-controlled drones as bombers.



Sikorsky HO3S-1

Despite its limited range, fragility, and vulnerability, the Marines' air ambulance version of the Sikorsky H-5 evacuated the wounded from the front lines. Pilots retrieved by an "Angel" had to ride outside the aircraft until the roomier H-19 was operational.



Boeing B-29 Superfortress

The heavy bomber carried the war to all parts of Korea until MiGs made daylight bombing too costly. It then took up night bombing, with its underside painted with black lacquer to frustrate searchlight tracking. KB-29s provided inflight refueling; RB-29s flew strategic reconnaissance.

Jet Meets Carrier

Speaking for the many pilots who traded in their piston engine fighters for jets during the Korean War, Captain Gerald G. O'Rourke wrote, "The sensations were truly weird." In *Night Fighters over Korea*, his memoir of flying the Douglas F3D Skyknight, O'Rourke describes his first jet flight, in a McDonnell F2H-4 Banshee: "I felt naked and unprotected sitting way up front, without a prop and a huge engine blocking my view.... There was very little noise, save the crackling of the radio and gushing of the plane's ventilation and pressurization system. The plane wouldn't strain at a turn the way a prop did, and slow speed flight was entirely different."

Operating these strange creatures from aircraft carriers was also entirely different, and the record of naval operations early in the war reveals the pain of rushing into combat with aircraft whose performance was poorly understood by pilots who'd had too little time to train on carriers not at all suited to the demands of jets. One jet squadron suffered 35 accidents in its first two months at war.

The chief undoing of carrier pilots in Korea was the necessity of parking aircraft on the carrier deck, which doubled as the landing strip. If its tailhook failed to grab an arresting wire on landing, the aircraft ran forward into a series of wire barriers. If those failed to hold, the aircraft stopped by smashing into the parked aircraft beyond. Modern carriers have decks with runways angled away from the ship's axis. They also have steam catapults and mirror landing systems, but none of these was available when the Korean War began.

The late Admiral Donald D. Engen, former director of the National Air and Space Museum, recalled in *Wings and Warriors: My Life as a Naval Aviator* (Smithsonian Institution Press, 1997) how the deficiencies affected all types of aircraft. The following relates his experience as a Grumman F9F Panther pilot aboard

the USS *Valley Forge* in the Sea of Japan:

July 4 [1950] was one of those days that aircraft carriers do not like to have. During the first recovery that morning, an AD with minor [anti-aircraft artillery] damage came in high and fast and after the cut floated over the wires and barriers to pass by Commander Blackie Wienel and me in Primary Fly at eye level. Blackie hit the emergency alert switch to announce heads up on the flight deck for all to hear and to enable them to take cover wherever they could find it. The AD landed with a thunderous smash on top of the air group airplanes parked farther forward on the flight deck. Parts, propeller blades, and dust flew in all directions, and when everything came to rest, not one person had been hurt....

That "act" was followed by an F4U with moderate battle damage that could not lower one main wheel. The pilot made his approach for landing after all

aircraft were on board. His hook caught a cross-deck pendant as his right wing slammed to the deck. No sooner had that occurred than the HO3S-1 helicopter manning the plane guard station aft of *Valley Forge* reported an engine failure and hit the water in a great splash. The Helo pilot was rescued by the plane guard destroyer, while the mess on the flight deck was sorted out. Finally, another AD floated over the wires after the cut but remained low enough to hit all three barriers and then to end up in a mess of wire spaghetti on the flight deck just below Primary Fly. Again, no one was injured, but it was not a good day.

No one had been shot down in combat on July 4, but we managed to lose

A Banshee crashed on the USS Essex in September 1951, killing seven. Cold day in hell (opposite): The USS Valley Forge in early 1951.



NATIONAL ARCHIVES (2)

JUNE 13, 1951

U.N. forces dig in on the 38th Parallel.

JULY 10, 1951

Truce talks begin at Kaesong; Communists break off talks six weeks later.

SEPTEMBER 23, 1951

U.N. forces take Heartbreak Ridge after 18-day battle.

NOVEMBER 27, 1951

Truce talks resume at Panmunjom.

DECEMBER 13, 1951

For second time, Sabre pilot George Davis downs four MiG-15s in one day.

three aircraft and damage seven others in the second day of combat!...

U.S.S. *Valley Forge* was limited in its air operations by the capabilities of its H-4 catapults and its arresting gear. Our jet airplanes always taxed those capabilities to their limits, and as a pilot you could feel the punishment in your body on the catapult shot or arrested landing. The ship could make 30 knots, but we needed in excess of 35 knots of wind across the deck so that we would not exceed the airplane's or the ship's catapult and arresting gear capabilities. In August some days the F9Fs could not fly because there was not enough wind across the deck, so we would simply stand down. That happened infrequently, but we pilots in VF-51 and VF-52 took some heavy ribbing from our friends in F4U and AD squadrons when it did.

As Navy pilots gained experience, U.S. forces came to rely on carrier crews for interdiction and combat air patrol. Because carriers were stationed so near the Korean coast, crews were always alert for an attack on the fleet. On November 18, 1952, the attack came. Cruising about 100 miles south of Vladivostok, the USS *Oriskany* picked up aircraft approaching from the north. "Few doubted the origins of the bogies," writes historian Richard Hallion in *The Naval Air War in Korea*; "the direction of the contact pointed at the heart of the Vladivostok naval and air complex, and—the clincher—radio intercepts picked up Russian being spoken by the pilots." The *Oriskany* launched four F9F-5 Panthers to intercept what turned out to be seven MiG-15s; one F9F lost a fuel pump and returned to the ship. Pilots John Middleton, E. Royce Williams, and David Rowlands engaged the MiGs, and Williams shot one down quickly. An excerpt from the squadron report describes the rest:

As Rowlands reached the scene of action, a MiG made a head-on run, firing from far out and breaking sharply



to the left in a steep climbing turn. With planes all around him, Rowlands found himself in an advantageous position with a MiG in his sights. Firing a long burst, he started it smoking but was diverted by another jet attacking him. The MiG and the F9F-5 ended up circling with neither jet gaining the advantage.

Another MiG turned inside Williams and scored a hit, seriously damaging the F9F-5.... With the MiG still firing on his tail, Williams dove for a cloud bank 10,000 feet below him and approximately ten miles away. Rowlands followed although out of ammo by this time. He flew almost a loose wing position on the enemy jet in an effort to drive him off.

About this time Lieutenant (junior grade) John D. Middleton was vectored up to aid his two squadron mates. His indoctrination to aerial combat was a head-on run by one of the swept-wing jets who came in from the two o'clock position. Lt. Middleton countered him

and simultaneously saw Williams, a MiG, and Rowlands diving toward the cloud bank. As he broke to render aid, a MiG made another run on Middleton. On breaking away, the enemy plane reversed course and apparently lost the F9F-5 in the sun, for he remained in perfect position for a 90-degree deflection shot. Middleton tracked him, fired from far out, and continued firing as the MiG's superior speed caused the Panther to tail in behind him. The pilot bailed out and Middleton saw the plane crash into the sea....

All three pilots made it back to the *Oriskany* and, with two kills to their credit, may have won more than the battle. The enemy left the carriers alone. But the feeling of vulnerability remained, and after the war the Navy rushed development of long-range early-warning aircraft and experimented with the Tail Sitters—interceptors that could take off and land without a runway in the immediate defense of the ship.

JUNE 23, 1952

500 U.S. fighters take off from bases and carriers to strike hydroelectric plants.

JULY 11, 1952

U.N. air forces launch attack on P'yongyang rail yards and industrial facilities.

MARCH 19, 1953

Navy aircraft attack Chongjin, ravaging the industrial center.

MARCH 28, 1953

North Korean and Chinese leaders agree to POW exchange.

APRIL 18, 1953

Three-day battle of Pork Chop Hill ends in victory for U.N. forces.

The Distant War

Compared with the copious output inspired by World War II, the number of novels and movies that have emerged from the Korean War is small. The latter conflict was conducted far from the U.S., and in a part of the world Americans knew little about, and maybe that's partly why it never seeped very deeply into our popular culture. One well-researched depiction is *The Bridges at Toko-ri*, a novel by James A. Michener (and later a movie) in which a squadron of U.S. Navy pilots is tasked with bombing four bridges, based on real ones targeted in the region of North Korea nicknamed "Carlson's Canyon." In this scene, the hero, Reserve pilot Harry Brubaker, confides his doubts about the war to his commander, Admiral George Tarrant.

The admiral, far back in his corner of the davenport, studied the bundled-up young man and jabbed his coffee cup at him. "Harry, you're one of the

finest pilots we have. You go in low, you do the job."

Brubaker grinned.... "From you, sir, I appreciate that."

"Then why don't you stay in the navy? Great future here for you."

The grin vanished. "You know what I think of the navy, sir."

"Still bitter?"

"Still. I was unattached. The organized units were drawing pay. They were left home. I was called. Sometimes I'm so bitter I could bitch up the works on purpose."

"Why don't you?" Tarrant asked evenly.

"You know why I don't, sir. The catapult fires. There's that terrific moment and you're out front. On your way to Korea. So you say, 'What the heck? I'm here. Might as well do the job.'"

"Exactly. The President once rebuked me publicly. I'd had that big fight with

the battleship boys because they didn't think aviation was important. Then the brawl with the air force who thought it too important. I know I'll never get promoted again. But you're here and you do the job."

"It would be easier to take if people back home were helping. But in Denver nobody even knew there was a war except my wife. Nobody supports this war."

[W]hat the young pilot said interested him. "Every war's the wrong one.... But that's the one [we're] stuck with. That's why, one of these days, we'll knock out those bridges at Toko-ri.... I believe without question that some morning a bunch of communist generals and commissars will be holding a meeting to discuss the future of the war. And a messenger will run in with news that the Americans have knocked out even the bridges at Toko-ri. And that little thing will convince the Reds that we'll never stop...never give in...never weaken in our purpose."

From *The Bridges at Toko-ri* by James A. Michener. Copyright ©1953 by James A. Michener. Reprinted by permission of Random House, Inc.

The war's most lyrical chronicler has been novelist James Salter, who served in the conflict as an F-86 pilot. The following is from his 1956 novel *The Hunters*.

Then it was intoxicating. The smooth takeoff, and the free feeling of having the world drop away. Soon after leaving the ground, they were crossing patches of stratus that lay in the valleys as heavy and white as glaciers. North for the fifth time. It was still all adventure, as exciting as love, as frightening. Cleve rejoiced in it.

They climbed higher and higher, along the coast. It became difficult to distinguish earth from water where they met. The frozen river mouths blended into



APRIL 26, 1953

Full peace talks resume at Panmunjom.

MAY 3, 1953

Skyraiders from *Valley Forge* hit key Chosin power plant with surprise night attack.

JUNE 14, 1953

Communist offensive pushes Republic of Korea troops south.

JUNE 18, 1953

South Koreans release 27,000 North Korean POWs, who refuse repatriation.

JUNE 25, 1953

"Little Truce Talks" secure Republic of Korea's acceptance of armistice.

white land areas. The rice paddies south of Pyongyang looked like cracked icing on pale French pastry. He saw the knotted string of smoke go back as Desmond test-fired his guns....

In half an hour they had reached the Yalu, an unreal boundary winding far below. The sun was higher now. The sky was absolutely clear. His sunglasses made it a deeper blue, like deep ocean. He could see a hundred miles into a China that ended only with a vast horizon, beyond the lives of ten million rooted people. At forty thousand feet they patrolled north and south, turning each time in great, shallow sweeps.

They had been doing this for about ten minutes when somebody called out contrails north of the river. Cleve looked. He could not see them. Then he heard.

"They're MIGs."

He heard Desmond: "All right, drop them."

He dropped his tanks. They tumbled away. He looked north. Still he saw nothing. He was leaning forward in his seat, intently. He stared across the sky with care, inch by inch.

"How many of them are there?" somebody asked.

"They're MIGs!"

"How many?"

"Many, many."

...Then at last he saw them, more than he could count. It seemed unbelievable that he had been unable to locate them only seconds before. He could not make out the airplanes, but the contrails were nosing south unevenly, like a great school of fish. They were coming across the river. They were going to fight.

From the book *The Hunters*. Copyright ©1956 by James Salter. Reprinted by permission of Counterpoint Press.

Of course the most famous depiction of the Korean War is *MASH*, first a novel, then a movie, and finally a long-running television series. Korea was the first war in which the helicopter played a role, and one of its main

functions, especially for the Bell H-13 Sioux, was evacuating casualties to nearby MASH—Mobile Army Surgical Hospital—units.

The six o'clock chopper, either morning or evening, was always unwelcome because the very fact that the pilot was risking the trip in half-daylight meant that the soldiers lying in the pods were seriously wounded. So twice each day, at dawn and at dusk, as six o'clock approached, everyone—surgeons, nurs-

es, lab technicians, corpsmen, cooks and mostly Lt. Col. Henry Blake—would listen, and during the time of the Great Deluge, they would hear, not one six o'clock chopper but three or four.

[One evening, while taking a cigarette break outside the MASH, some personnel notice a strange change of routine—no helicopters.]

"O'Reilly," Henry said, "it's six o'clock."

"Nothing, sir."

"It's six-oh-five."

"Nothing, sir."

"O'Reilly," the colonel said, at about six-fifteen, "I can't see my watch any more."

"Nothing, sir....

There was no jubilation. They were all too tired. In fact, they were exhausted, completely spent, and the Swampmen [the three main characters, surgeons who are quartered together] hit their sacks. When 6:00 A.M. came and went, and there were no choppers, they slept on, and at 8:00 A.M., when Radar O'Reilly, accompanied by an associate lab technician, entered The Swamp, he could have made any of the three the victim of his desperate need....

"Captain Forrest?" he said, shaking the Duke. "Sir?"

"Not now, honey," the Duke mumbled. "Gobacksleep."

Gently, Radar straightened Duke's right arm.... Duke stirred but did not awaken, and while the assistant tightened the sleeve of Duke's T-shirt to serve as a tourniquet, Radar skillfully inserted a No. 17 needle into the vein and joyfully extracted a pint.

"Where'd you get it?" Colonel Blake asked, after Radar had hurriedly cross-matched it and proudly presented it to his chief....

"I found a donor, sir," said Radar.

"Good boy," said the colonel. 

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JUNE 25, 1953

Chinese launch massive attacks against South Korean divisions.

JULY 10, 1953

Communists return to negotiations.

JULY 25, 1953

Pilots of Task Force 77 fly 538 offensive and 62 defensive sorties—their single-day record.

JULY 27, 1953

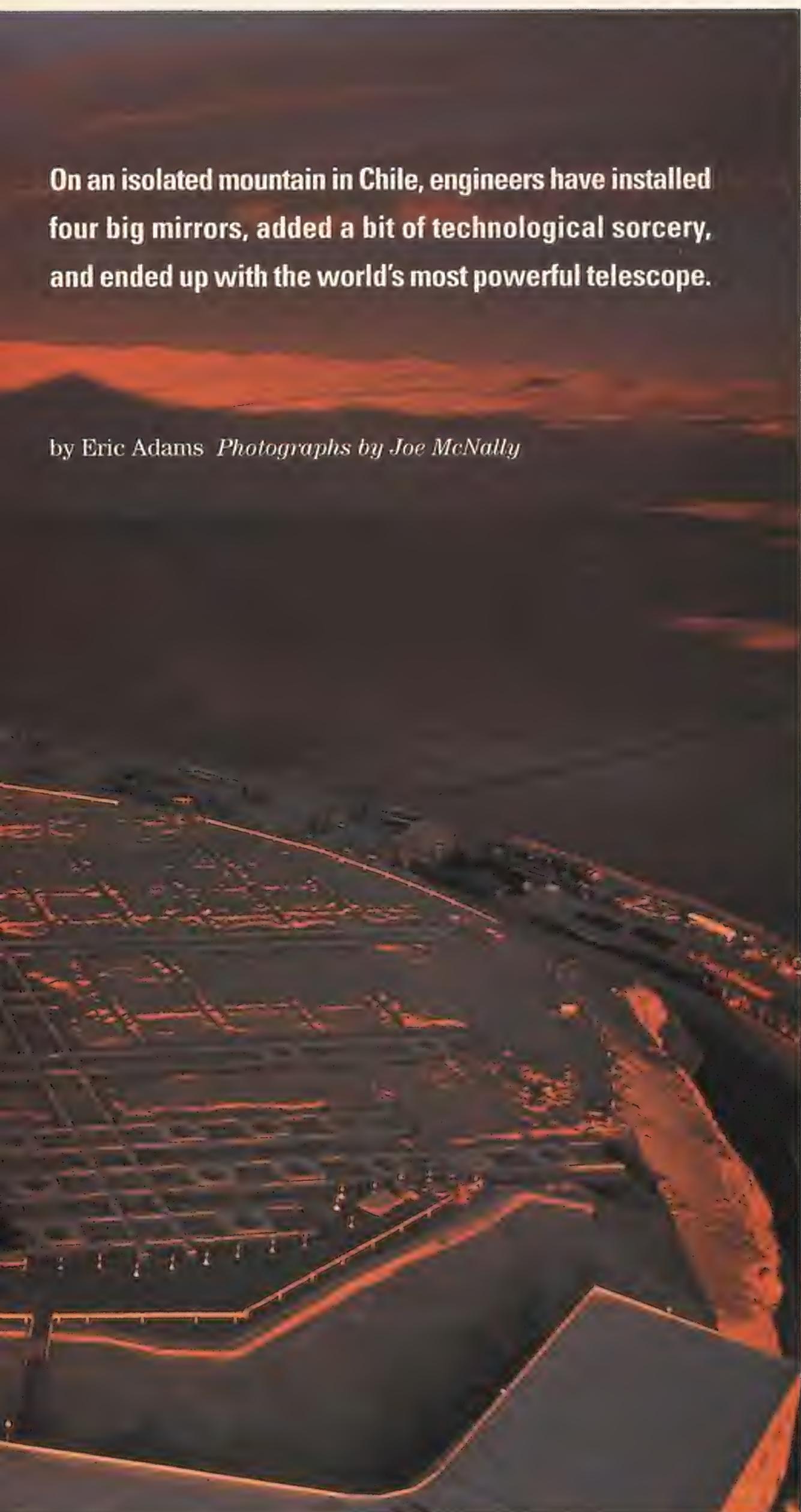
Cease fire signed; fighting ends 12 hours later.

SEPTEMBER 4, 1953

Processing of POWs for repatriation begins at Freedom Village, Panmunjom.

Light and Magic





On an isolated mountain in Chile, engineers have installed four big mirrors, added a bit of technological sorcery, and ended up with the world's most powerful telescope.

by Eric Adams *Photographs by Joe McNally*

In the world of big, powerful telescopes, there is one accomplishment that none have been able to claim. It has no scientific value, really, but it would thrill both astronomers and the general public and ensure a lifetime of bragging rights to the first to do it.

Sitting in his office at the European Southern Observatory's Very Large Telescope in northern Chile, overlooking an expanse of brown hills and valleys leading to the Pacific Ocean five miles away, VLT director Roberto Gilmozzi smiles as he edges toward the revelation. "When this telescope is complete, it will have the angular resolution equivalent to that of a telescope with a mirror 132 meters [433 feet] in diameter," Gilmozzi begins. "That means that we will, if we wanted to, be able to resolve and photograph Apollo debris left on the moon."

In the Atacama Desert, the VLT's four telescopes and its interferometric tunnels, to the right, are nearing completion.

Now, there are many, many other celestial targets that the ESO is much more interested in—distant galaxies, dim nebulas, extrasolar planets—but that would be a sensational stunt. Many thought it impossible, given how minuscule even the largest Apollo remnant—something about the size of a delivery van—would be from a quarter of a million miles away. But with the giant leap that the ESO is about to take in Chile, this and a lot of other accomplishments are indeed going to be possible. Gilmozzi is coy, though, about whether the moon shots will actually make it into the observing schedule. “It would certainly make for some good PR, wouldn’t it?” he asks.

It would. It would also prove Gilmozzi’s point: that the VLT is an exceptionally powerful instrument. Built atop a truncated mountain in the Atacama Desert, the VLT is actually four identical 8.2-meter-diameter reflecting telescopes—two of which are now operational—that can be used independently or be linked, through a process called interferometry, to create what is essentially a single ultra-large-aperture telescope. Technologies called active and adaptive optics, plus a prime geographic location—one of the driest places on earth—will enable the VLT to operate with virtually no atmospheric distortion, and its remote location will also give it the darkest skies possible. All of this will make the VLT capable

One of the VLT’s beryllium secondary mirrors, still with its protective cover, was placed in its \$20 million housing in January (below). After engineers removed a delicate primary mirror from its transport box, they began carefully peeling off its protective layer.



of seeing farther and in greater detail than anything before it. It will capture images at least 50 times sharper than those obtained by the Hubble Space Telescope. It will answer many questions, and raise many new ones—and it will probably place Europe at astronomy’s fore.

“The VLT is already the best-working telescope in the world,” says British cosmologist Simon White, director of the Max-Planck Institute for Astrophysics in Munich. White visited the VLT last year to capture details of the rotation of spiral galaxies. “This is the first time in a century that the foremost optical astronomy instrument has been a non-U.S. facility. When complete, the VLT interferometer will open an entirely new range of phenomena for study—if it works to spec.”

The VLT’s potential isn’t lost on the Americans. Says Robert Gehrz, president of the American Astronomical Society and a University of Minnesota physics and astronomy professor: “If they can get that thing to work as an interferometer, that’s going to be a breakthrough that will make it the most powerful facility in the world. There’s no question about that—and I’ll probably be applying for time on it.”

The VLT was conceived in 1977; in the years since, the ESO, a consortium made up of Germany, Italy, Denmark,

France, Belgium, Sweden, Switzerland, and the Netherlands, has spent \$500 million on it. All of its major advances have been tested at the New Technology Telescope in La Silla, Chile. But the VLT is one of the most complicated observatories ever built, and its success won’t really be verified until 2006, when its four telescopes focus on the same speck of light and it begins coming up with answers to questions about galactic evolution, the insides of quasars and black holes, and, Gilmozzi promises, the precise nature of the planets orbiting stars other than our sun.

The VLT may as well be on another planet itself. Getting to Cerro Paranal, the mountain on which the VLT was built, is a multi-leg, often multi-day affair. Visitors fly first to Santiago and then 800 miles north to Antofagasta, an isolated, sprawling port city of 250,000 that exists primarily to support the dozens of mines in the region. Here, families flock to the rocky beaches—better for sunbathing than swimming—that span Antofagasta’s western shore.

From the ocean, the trip east entails a bone-jarring 75-mile drive into the Atacama Desert, a dusty plateau on the edge of the Andes that is virtually devoid of vegetation and animal life. There is little but gently sloping mountains and vast fields of boulders that



COURTESY ESO/2

sit evenly distributed, as if placed by a machine. The wide dirt road, called the Old Panamerican Highway, is mostly used by the observatory and by a nitrate and iodine mine about 20 miles beyond the telescopes. There is nothing along the way, and trouble (breakdown, blown tire, accident) means either a long walk or a long wait. Visitors who don't take the ESO's shuttle and elect to drive themselves are instructed to call the observatory before leaving. If you don't show up in three hours, they send someone out to find you.

Eventually, a large white sign materializes, announcing the presence of the VLT. Behind it, a freshly paved road vanishes into the hills—a 280-square-mile region that Chile donated to the ESO in exchange for telescope time. A slow first-gear ascent leads to the guard shack and the observatory base camp, which sit 7,750 feet above sea level. From here, you can visually follow a two-mile road up the mountain's remaining 900 feet to its perfectly flat top, where four giant silvery cubes perch, with rocks dribbling over the sides—debris produced when the builders blew 90 feet off the top of Paranal in 1990.

The base camp below is a clean, orderly village that is mostly made up of bright white ship cargo containers that have been converted into surprisingly nice offices and dorm rooms. On one side of the camp sit a helicopter pad and a soccer field; on the other, a parking lot filled with white four-wheel-drive trucks bearing ESO logos on the doors. Scattered throughout are a two-story telescope service building, a platform with eight 20-foot-tall water tanks that get replenished twice daily by trucks from Antofagasta, a power station, and a dormitory being built for staff and visitors.

Beyond this, there is nothing. As workplaces go, Paranal has little appeal. Though serene and beautiful, it is also hot and dry, and far from any

For transport, mirror and cell were placed on an air cushion vehicle (top) that held the cell in place under the bottom of each telescope. The movable part of each telescope structure weighs 470 tons and rests on oil pads.



COURTESY ESO (2)

diversions. "Personally, I consider Paranal to be one of the better places on the Earth to read books," says VLT staff astronomer Gianni Marconi, a friendly 39-year-old Italian who spends his nights on the mountaintop operating the telescopes for visiting astronomers. "I'm used to walking far from the base camp to where human-produced noise disappears and I am disturbed only by the wind." Visitors aren't encouraged to take such walks, though: Two who wandered off last year quickly became disoriented in the

One of UT1's first images: large spiral galaxy NGC 1232 (right). One hundred million light-years distant, the galaxy's central areas contain reddish older stars, while the spiral arms are populated by young blue stars and star-forming regions. Prior to sunset, VLT personnel open the telescopes' domes to allow temperatures inside and out to equalize.

featureless hills and ended up lost for two days.

But for astronomers, the lonely desert site has several advantages: the dry air, which makes for clearer skies and a low risk of condensation collecting on telescope mirrors; the distance from any sources of the urban light pollution that plagues much of the world; and the roughly equatorial positioning, which gives it access to objects in both northern and southern skies.

When the sun goes down and the night sky emerges, any doubts about

why someone would travel so far for this are squelched. Scrolling up from the east, the Milky Way shines steadily against the deep-black sky, with dozens of fuzzy nebulas and star clusters visible to the naked eye. Two galaxies, consuming startlingly large swaths of sky, hover in the south: The Large Magellanic Cloud spans the width of about 14 full moons; the Small Magellanic Cloud, six. On this mountain, you feel as if you are staring *out* into space, rather than merely up at the stars.

On the telescope platform at dusk, the four 100-foot-square silver enclosures, each containing a five-story telescope, await instructions to open their doors and commence their night's work, either observation or, for the unfinished scopes, calibration and testing. All are cast in a shimmery reddish yellow from the sunset. Massimo Tarenghi, the VLT's project manager, stands amid a somewhat treacherous network of half-finished concrete channels and open pits that will soon contain the in-



A Lot of Windex

terferometry hardware. He wonders if the project will end up spoiling his colleagues: "Will we ever be able to work on a telescope that isn't at least as big as this?" he asks.

Though it isn't quite dark yet, the doors to Unit Telescope 1 slowly crank open and the dome rotates around to face south. This process helps ensure that the temperature of the air inside of the dome equals that of the air outside; inequalities would produce turbulence, which would distort the observed images.

Tarenghi notes that every major component of the telescope had a team of engineers dedicated to it. One group designed the 8.2-meter primary mirrors. Another focused the active optics system, which compensates for changes in the thermal conditions around the telescope and for tilt-induced weight changes that would alter the mirror's performance. Still another team mastered the \$20 million secondary mirror system, which collects light focused by the larger primary mirror and directs it into the telescope's instruments. This system consists of a five-foot-long cylinder with a beryllium mirror on the bottom, and within it hundreds of pounds of electronics that constantly adjust the mirror's angle—another part of the telescope's active optics system. The secondary mirror hovers 40 feet above the primary and resembles a satellite in structure.

In each of the telescopes (UT1 through UT4), all of this hardware rests on a two-axis alt-azimuth mount that itself floats in a narrow track on a layer of oil only 0.05 millimeter thick. This makes for exceedingly smooth action—the whole 470-ton telescope can be moved with only a nudge of a hand. Of course, the motion of the telescopes is actually controlled by computers, from initial positioning to tracking of celestial objects during prolonged imaging and study. In the control building, a separate cluster of computers operates each telescope and provides continuously updated visibility conditions and tracking information. A fifth cluster of computers will call the shots when the interferometric mode becomes functional.

Though there is much for the VLT's engineers to brag about, several tech-

nological triumphs stand out. The first are the mirrors and their control mechanisms. The 8.2-meter Zerodur glass disks are among the largest single-piece telescope mirrors in the world. Manufactured in Europe, they were brought separately to South America on ships and then sent on a painstaking journey from Antofagasta to Paranal. Preceded by several grading trucks that smoothed out the dirt road, the trucks bearing the fragile mirrors drove a steady 3 mph. The trip took three days.

The 540-square-foot mirrors were aluminized in the ESO's mirror maintenance facility at Paranal, then inserted into basket-like cells and driven the final two miles up to the enclosures. These cells contain the 150 active optics actuators, small hydraulic pistons that flex the seven-inch-thick mirror in sub-millimeter increments.

Once light reflects off the actively controlled mirrors, it is further enhanced at an adaptive optics filter, which also employs a deformable mirror and works to counter errors, such as high-altitude thermal changes and atmospheric turbulence, that occur more rapidly than those the active optics can correct. These conditions are monitored by focusing on a single guide star; in response, the computer orders changes in the mirror's shape 100 times per second. Though several observatories around the world, most notably the Subaru Telescope atop Mauna Kea, Hawaii, are applying or developing active and adaptive optics, the VLT is by far its largest application, and the ESO was one of the first organizations to develop the technology. "When we were developing the active optics system in the 1980s, nobody was sure that this would work at this scale, and many people actually opposed the idea," Tarenghi recalls.

The other remarkable achievement taking shape on Paranal is the VLT interferometer. This setup, common in radio astronomy, capitalizes on the fact that if a telescope has a larger aperture, it can collect more of the light from objects in space. Interferometry enables the four telescopes to focus on the same object and gather its light as if the group were a single telescope as big as the combined distances between the individual tele-

If you think the Very Large Telescope is big, just wait. The industrious European Southern Observatory is already several thick reports into its next huge project, the OWL, or OverWhelmingly Large Telescope. If all goes as planned, the OWL (artist's conception below) will begin scanning the heavens with a colossal 100-meter mirror sometime in the next few decades.

The idea, which is being pursued by other agencies tinkering with so-called extremely large telescopes, is to create a telescope that doesn't rely on interferometry, or groupings of multiple telescopes, to achieve such sizes (compare the capacity of a single big bucket to that of four thimbles). The OWL's mirror will have a surface area of 7,800 square meters—equivalent to 10 times the combined surface area of all observatories ever built. The increased light-gathering ability will enable astronomers to probe even deeper into distant galaxies and thus farther into the universe's past, compared with what the VLT allows. Indeed, one of the main objectives of the OWL's development team is analyzing the spectra of the remote galaxies of the famous "Deep Field" image that the Hubble Space Telescope caught in 1995.

The telescope, which will probably consume another big chunk of Chilean real estate, will employ adaptive optics, rest on a two-axis alt-azimuth mount, measure about half the height of the Eiffel Tower, and wield a segmented mirror made up of 2,000 7.5-foot pieces.

ESO scientists have been studying the technologies and costs, and have developed three scenarios: what can be done with \$1 billion, \$10 billion, or, in a perfect world, an unlimited budget.



CIELE ET ESPACE



COURTESY ESO (2)

Dutch astronomer Peter Barthel used the VLT to capture a stunning image of the Sombrero Galaxy (above) for his own research, and, with colleagues, got the first optical image of a distant radio galaxy early in its life (left, in crosshairs). He plans to analyze the latter spectrographically. Poised for greatness, the VLT array (opposite) promises stellar performance.

scopes—in the VLT's case, a distance of 426 feet.

Light beams collected by the four telescopes are deflected by mirrors into underground tunnels, where they are gathered at a single sensor. The sensor generates an image that is a cumulative product of the four beams. The trick is getting the light waves to meet at the sensor at the same time: As objects are tracked, the telescopes' relative positions change. Consequently, in the tunnel, the light is bounced off several retro-reflectors sitting on small, precisely positioned rail carts that move on 200-foot tracks to compensate for these changes. In addition, three small auxiliary telescopes, also moveable, on the surface will fill in the spaces between the four UTs to further punch up the resolution.

Final processing will prove that the VLT is far greater than the sum of its parts, with an angular resolution of 0.001 arcsecond. (The "celestial sphere" around Earth is 360 degrees; the full

moon has an apparent size of 0.5 degree; a degree has 60 arcminutes; an arcminute has 60 arcseconds.) The Hubble, which sits above the atmosphere but has only a 2.4-meter mirror, can resolve to 0.1 arcsecond. The VLT's resolution is fine enough to capture detailed images of distant galaxies, clues about the chemical and biological composition of extrasolar planets—and snapshots of lunar rovers.

Putting all this to work means long nights on the mountain. In the evening, the base camp is pitch dark (no exterior lights are permitted, with the exception of a few dim safety lights) and increasingly silent as the lively chatter and music coming from the dorms of the ESO's 150-plus Chilean and European engineers and administrative and support staff gradually taper off. But atop Paranal, in the control building—already decorated with posters of some of the more spectacular images captured through UT1—a steady buzz of activity lasts until dawn. On

average, the observing conditions (the "seeing") are considered excellent 350 days a year, a number envied by most observatories. On those evenings, the telescopes and their attached instruments work feverishly to flush every photon of light-borne information out of the sky.

The scheduling of science operations at the VLT is controlled at the ESO's headquarters in Garching, Germany. Astronomers compete for observing time, and if their proposal is accepted, they can travel to Chile to supervise the session themselves—as might be necessary for complicated or variable-dependent projects—or request that the VLT's staff astronomers, such as Marconi, conduct the program on their behalf. Marconi also operates the VLT for visiting astronomers, so that they don't lose time struggling with the technology.

The scientific programs Marconi helps execute are challenging, chosen to push the VLT's capabilities as far as possible. The results are sometimes breathtaking. "We made an observation three weeks ago which is particularly alive in my mind," Marconi recalls. "The target was a jet of material ejected from the famous active galaxy 3C273. While looking at the details obtained in the images, I forgot for a moment that I was on the ground."

The VLT will undertake a variety of scientific projects, including measuring the universe, studying galaxy structure and formation, and observing star birth and planetary system formation. Director Gilmozzi is confident that the VLT will push astronomy even further. "There's a final question that astronomers are asking, and that's whether we are alone in the universe," he says. "We will soon begin to ask how to detect biospheres and ecospheres on extrasolar planets, and the VLT will make those searches possible. I'm also sure that over the next several decades we will discover an enormous class of objects of which we have no hint today."

Along the way, ESO hopes to develop new strategies for studying astronomical phenomena. Instrumentation plays a key role in this. The VLT will initially be outfitted with 11 instruments—some as big as a room—capable of wide-range spectroscopy

and other types of imaging. Some of these instruments have already paid big dividends for astronomers using UT1. Munich University's Rolf-Peter Kudritzki spent four nights at Paranal late last year using the VLT's FORS—focal reducer/low-dispersion spectrograph—to examine a newly discovered population of stars floating in the space between the galaxies of certain clusters. Though Kudritzki's team came well prepared, the members encountered some surprising results and consequently had to alter their program on the fly. "Many of our objects turned out to be completely different from what we expected," Kudritzki says. "We detected a new class of extreme-emission-line galaxies at very high redshift." High redshifts indicate that the galaxies are moving away from our own very quickly and are at the edge of an expanding universe; because they are so far away, their light took billions of years to reach Earth, so we are seeing them as they were when the universe

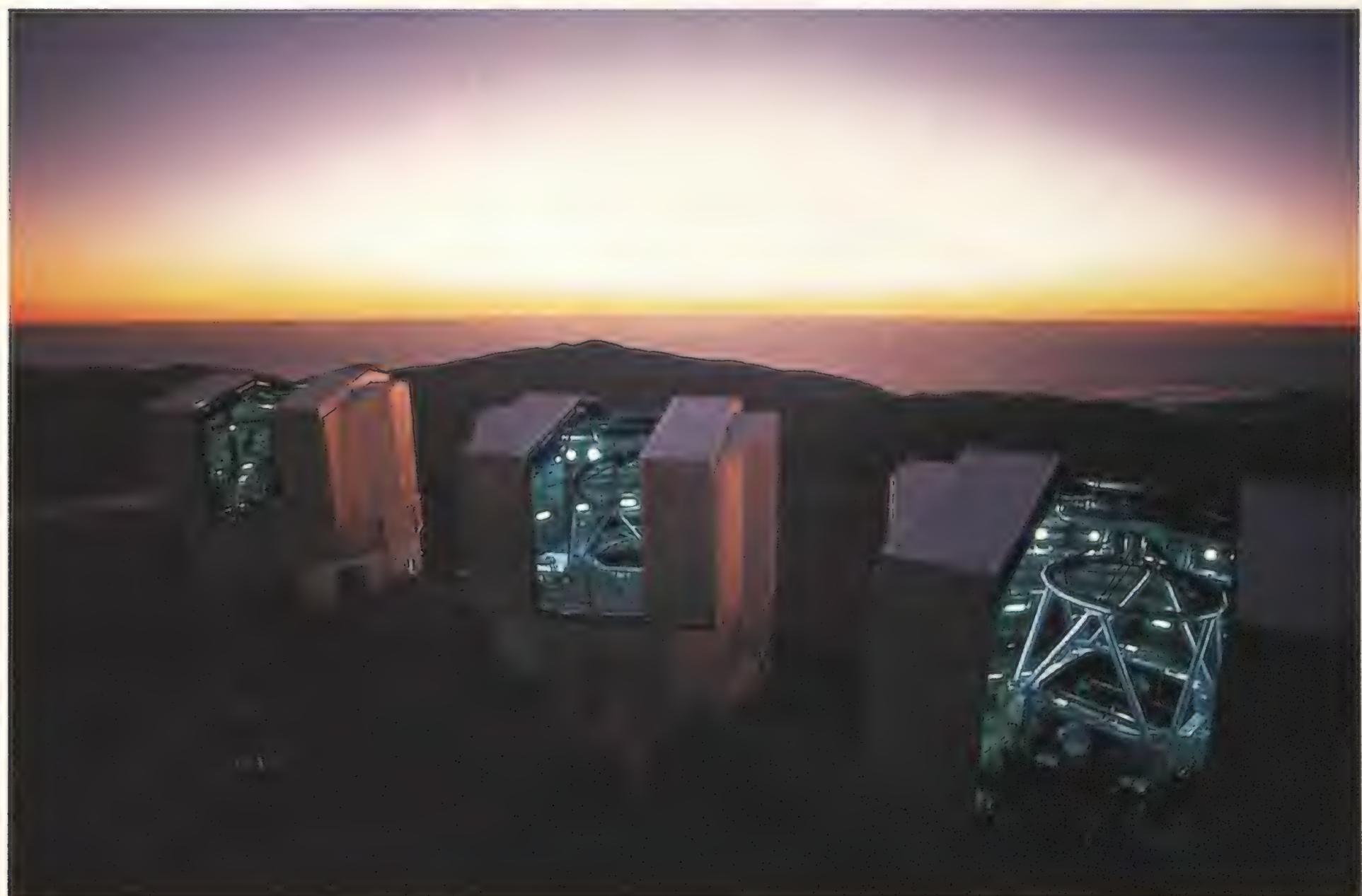
began. "I knew on the spot that I had something new and I was very excited about that," says Kudritzki.

Peter Barthel, an astronomer at the Kapteyn Institute in the Netherlands, spent several days at Paranal in late January. Collaborating with Willem de Vries of Lawrence Livermore National Laboratory in Berkeley, California, and Chris O'Dea of Baltimore's Space Telescope Science Institute, Barthel investigated distant galaxies that appear to be harboring small, young radio sources—potentially other galaxies. "The VLT data will tell if our ideas about these young radio galaxies make sense, and fortunately the data we gathered were excellent," Barthel says. "We got a number of new identifications with very faint galaxies. Though we still have substantial data processing and analysis left, we can, from the raw images, already see the faint host galaxies and study their spectra."

Barthel also devoted eight minutes of observing time to imaging the well-

known, and significantly closer, Sombrero galaxy, M104. He is completing a study on black holes in the center of similar galaxies, and felt the VLT would help. It did—and it made for an impressive picture (one that the ESO made into a poster). "The raw Sombrero data were of sheer beauty," Barthel recalls. "We were making live pictures of a beautiful piece of nature."

Sunrise at Paranal brings a temporary halt to the exploration—and these days a continuation of construction, as there is still much work to be done on the telescopes, the interferometry tunnels, and the new dormitory building below. After coming off the mountain and grabbing a bite to eat in the cafeteria, astronomers usually head for their rooms, which are all clustered in a corner of the container camp and marked with signs reading "Silence: Astronomers Sleeping." For them, this lonely place, bathed in light from suns both near and far, is paradise. 





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Learn to FLY

Always wanted to try it, but didn't know how to start? No more excuses.

by Scott M. Spangler *Illustrations by Richard Thompson*

What surprised me most about learning to fly is that I flew the airplane on my first lesson. Sure, my instructor added subtle inputs on the rudder pedals and control yoke from time to time, but I was in control.

Since that incredible day, I've learned that pilots are not Saturday morning superheroes. Flying doesn't demand the Hulk's strength, Spiderman's reflexes, Superman's ability to see through walls, or Batman's mental horsepower. There are more than 618,000 pilots listed in the Federal Aviation Administration registry, and what distinguishes them from the population at large is only that they have completed a series of training classes. And there are so many reasons to do so.

Aerial Adventures

Whoever said one thing can't be all things to all people probably wasn't a pilot. The ways to integrate flying into your life are virtually endless. If you like to get away from it all, there's no better way to get there than by flying in. There are more than 18,000 public and private airports in the nation, many of them in places you can't get to except by aircraft. You can go where you want, when you want. And you don't have to go very far to get enjoyment from flying—just up. Being a few thousand feet up gives you an entirely new perspective on your own hometown.

Many people like to challenge themselves. As a pilot, you can pit your skills against other pilots, yourself, or the

sky. In airplanes and gliders you can fly aerobatics and compete in cross-country races in which your score is based on proficient, well-planned flying instead of outright speed. Other competitive events are based on the fundamentals of flying—the things all competent pilots learn—such as spot landings, the ability to place the landing gear precisely on a specific point on the runway.

You'll also find that airplanes are amazingly durable time machines. If you find the right vintage airplane, you can relive any era in the history of powered flight. Fly an open-cockpit biplane and be a barnstormer. You can also travel back in time by restoring an antique or by helping to preserve an aircraft in one of the hundreds of avia-





tion museums scattered across the globe. Almost all of them welcome volunteer caretakers.

Flying lets you re-create history—or make it. There are more than 700 kits and plans for airplanes, helicopters, and gliders you can build. Original designs or replicas of historic aircraft, they range from low and slow movers that let you enjoy the scenery below to pressurized, high-altitude screamers that make long trips short.

Learning to fly can also lead to a career, and working for an airline isn't the only option. Careers in aviation include inspecting power lines as well as flying corporate jets and part-time jobs like banner towing and flight instruction.

Who Can Fly?

Today, people learn to fly at an average age of 45. You can start taking lessons at any age, but you can't make a solo flight in a powered aircraft until age 16. You must be 17 to earn a pilot's certificate. Glider and balloon pilots can solo at 14 and get a pilot certificate at 16. There is no maximum age limit. The FAA requires airline pilots to retire at age 60, but in general aviation (flying that's neither commercial nor military),

pilots can fly as long as they have a medical certificate.



The FAA issues three classes of medical certificates—third, second, and first—to pilots who fly powered aircraft. (Medical certificates are not required for pilots who fly gliders and balloons; they sign a statement testifying that they are in good health.) Only pilots who fly professionally must have a second- or first-class medical. Very few conditions will keep an aviation medical examiner—a physician the FAA has authorized to conduct flight physicals—from issuing you a third-class



medical certificate. There are many pilots on the rolls who are deaf, blind in one eye, paraplegic, or missing limbs. Naturally, these pilots must adhere to regulations specific to their condition. Deaf pilots, for example, can fly only to and from the approximately 17,000 airports that don't require radio communication. In most cases, if you can demonstrate to the FAA that you can fly safely, you can earn a pilot's certificate. Among the few disqualifying conditions are epilepsy, a heart transplant, or any condition that causes a person to lose consciousness.

If you have a driver's license, you can pass the FAA vision requirement, which is at least 20/40 with glasses or contacts. Color blindness isn't often a cause for concern, but you may have to take a test to make sure you can distinguish the colors necessary to be a safe pilot (red, green, blue, and white). The requirements for a second- or first-class medical are more stringent: 20/20 with glasses or contacts.

Pilot certificates don't expire; medical certificates do. If you're younger than 40, a third-class medical is good for three years. If you're older than 40, it's good for two years. As a student pilot, you won't need a medical certificate until you're ready to solo. But it's a good idea to get one earlier. If you're ready to solo but the medical examiner can't see you until next month, you'll wait until next month to solo. To locate an aviation medical examiner near you, visit the World Wide Web at ame.cami.jccbi.gov.

Building Blocks

The steps to becoming a pilot can be viewed as a series of building blocks. Each pilot certificate and rating the FAA issues allows you to do a certain type of flying. Regardless of what

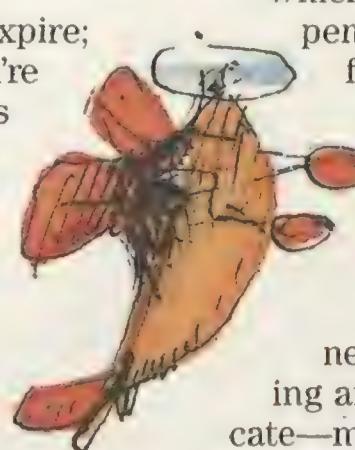
type you ultimately want to do, your first building block is either a recreational or private pilot certificate.

Recreational pilots can fly any airplane, helicopter, or gyroplane that



has fixed landing gear, no more than four seats, and a single engine that produces no more than 180 horsepower. Private pilots can fly any aircraft with fixed landing gear and a single engine with a maximum 200 horsepower. With additional training, private pilots can also fly more powerful aircraft that have retractable landing gear. To fly a multi-engine aircraft, you must have a private certificate and a multi-engine rating.

Recreational pilots are restricted to carrying one passenger at a time and flying only during daylight. Unless they have received additional training, they must not fly beyond 50 miles of their home airport, and they can fly only at airports that don't require radio communication. Private pilots can carry as many passengers as their airplane will safely accommodate, and they can fly anywhere day or night.



Which certificate you earn first depends on what you want out of flying. If you're flying for fun, the recreational certificate is a good way to get started. The private certificate is a good choice if you have career aspirations because it is the foundation that you'll need to earn an instrument rating and commercial pilot certificate—must-haves for a job as a professional pilot.

Regardless of which certificate you end up pursuing, you'll learn the stick-and-rudder skills all pilots must possess. Private pilots also learn how to fly cross-country, at night, and on instruments. (This instrument training is limited to the basics and doesn't permit private pilots to fly when the weather is less than ideal; it prepares them for the training that leads to an instrument rating, which is a separate rating appended to the others.)

In true building block fashion, recreational pilots can fly more than 50 miles from their home airport with a passenger by getting the cross-country training required of private pilots. This block requires at least three flight hours of training, as do the night and basic

instrument blocks. Recreational pilots can add these blocks at their convenience. There's no time limit. When they have all three they can take the test for a private pilot certificate.

The FAA requires recreational pilots to have at least 30 hours of flight training. A private certificate requires at least 40 hours. The difference seems small, but few people earn their certificates in the minimum time. On average, people take around 35 hours to earn a recreational certificate, and many do it by flying every day during a two-week vacation. It takes most people 55 to 75 hours to earn a private pilot certificate.

Ground School

Aviation education takes place on the ground as well as in the air. Subjects taught in ground school include weather, aerodynamics, the Federal Aviation Regulations (FARs, aviation's "rules of the road"), radio communications, navigation, aircraft systems, decision making, aircraft performance and what affects it, and preventing and dealing with emergencies.

You can attend an organized class, use a home study program, or learn one on one with an instructor. Many flight schools and community colleges offer ground school courses, which range from three-day cram sessions to once-a-week meetings that are held over several months. These courses often include field trips to aviation facilities such as control towers and maintenance shops.

If taking a class isn't convenient, you can study

privately with your instructor, though this tends to be a more expensive option.

Home study offers the most flexibility. Usually, these courses are composed of videotapes, a textbook, and often a computer program that allows you to review what you have learned. You won't have the human touch of a live instructor, but you can study when and where you want, and your instructor can always answer any questions later. In addition, you can repeat any lesson simply by hitting the rewind button.

Once you've completed the course-work, you'll have to take the FAA's



and-level flight, climbs, descents, and turns.

You'll learn and practice these elements and their combinations in a training aircraft, or trainer. An important consideration in choosing a trainer is the location of the airplane's third wheel. On most trainers it's on the nose, but on others it's at the tail. In the air, both types of airplane fly the same, but on the ground they handle differently, with the nose-wheel airplane being the more stable of the two and less affected by wind. This doesn't make taildraggers harder to fly, just trickier to handle on the ground, which is why pilots who learn to fly in a nosewheel airplane must have additional training before they can fly taildraggers. The reverse isn't true: Pilots who learn to fly in a tail-dagger don't need additional training to fly a "nose-dragger." Antique, vintage, homebuilt, aerobatic, and utility airplanes often have a tailwheel; if flying one of these airplanes is in your future, learning to fly in a tail-dagger would be wise.

No matter what type of aircraft you learn to fly in, you'll learn and practice a lot of emergency procedures. National Transportation Safety Board statistics reveal that pilot error causes nearly 80 percent of all general aviation accidents. No pilot takes off with the intention of having an accident, but some pilots make a series of bad decisions that lead to one. When the weather turns bad, continuing the flight rather than turning around or landing is a

knowledge test, which is administered by commercial computer testing services. For the recreational pilot test, you get two hours to answer 50 multiple-choice questions; for the private pilot test you get two and a half hours to answer 60 questions. A grade of 70 percent is passing.

Safety

You aren't required to take ground school before starting flying lessons, but doing so is a good idea because you practice in the air what you've learned on the ground. Flying isn't complicated, just three-dimensional. With the exception of learning to fly balloons, all the flying skills you'll learn are composed of four basic elements: straight-

RECREATIONAL
OR
PRIVATE PILOT

common example of poor judgment.

Demonstrating good judgment is a large part of the FAA practical test that you'll take as the final step in earning a pilot certificate. The test includes a check ride and an oral examination, and they will hold no surprises. An FAA booklet titled *Practical Test Standards* advises student pilots about the knowledge you must possess, the skills you must demonstrate, and the plus-or-minus tolerances you must maintain to pass the check ride.

How does the examiner assess your judgment? Let's say you're coming in for a landing and it's not going well. You have two options: Press on and try to save it, or abort the landing, go around, and try again. Pilots with good judgment go around. This not only impresses the examiner (making a good landing is safer than trying to save a bad one), it also fulfills a practical-test requirement: aborting a landing.

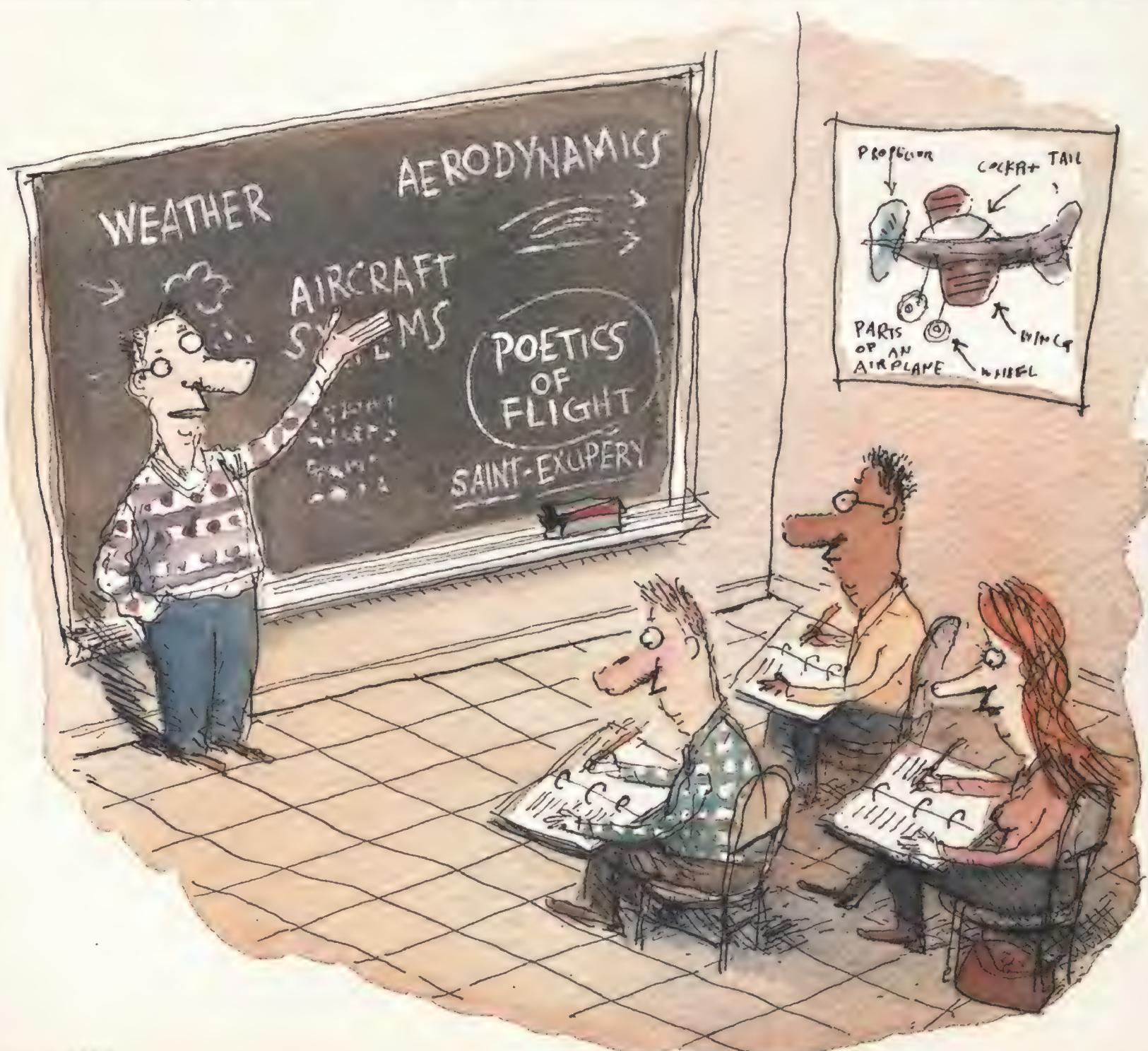
Teachers and Schools

Your certified flight instructor (CFI) will be your teacher, mentor, and guardian. Select this person with the same care you would a spouse because your success—and safety—depend on the quality of the instruction you get. When interviewing CFIs, ask a lot of questions. If you don't understand an answer, say so. This is imperative. How a CFI responds is a good indication of the quality of education you'll receive. A good teacher will rephrase an answer and will ask questions of you to ensure that you understand the material you've just been taught.

A good teacher is also organized and has a training plan. Without a plan there's a good chance you'll repeat some lessons and miss others. Have the CFI explain his training outline to you. (It's sure to be fodder for more questions.) Was the instructor on time for your appointment? Ask about his

schedule. A good teacher is worthless if your schedules don't mesh. Ask for the names of past students and talk to them to get an idea of what to expect.

After you've narrowed the field of CFIs, consider taking an introductory flight lesson with each finalist. (You can get a coupon, good at many flight schools, for a \$35 introductory lesson from Be A Pilot; see list on next page.) A good flight lesson starts before you get in the cockpit. First the instructor should outline in detail what you'll be doing. During the flight, the instructor should explain what's going on, but shouldn't gab nonstop. You need time to absorb what you're learning. And you should be doing a lot of the flying. Finally, no matter how trivial, take it seriously if something bothers you. Whether it's hygiene, vocabulary, or a personality quirk, a teacher's idiosyncrasies can distract, and if you're distracted, you're not learning.



Contact!

Here are some organizations that offer information about learning to fly and aviation career opportunities.

Air Care Alliance

4620 Haygood Rd., Suite 8
Virginia Beach, VA 23455
888-662-6794
www.aircareall.org

Aircraft Owners and Pilots Association

421 Aviation Way
Frederick, MD 21701
301-695-2000
www.aopa.org

American Helicopter Society

217 North Washington St.
Alexandria, VA 22314
703-684-6777
www.vtol.org

Balloon Federation of America

P.O. Box 400
Indianola, IA 50125
515-496-8809
www.bfa.ycg.org

Be A Pilot

888-BE-A-PILOT
www.beapilot.com

Civil Air Patrol

105 South Hansell St.
Maxwell AFB, AL 36112
800-359-2338
www.cap.af.mil

Experimental Aircraft Association

P.O. Box 3086
Oshkosh, WI 54903
920-426-4800
www.eaa.org

Helicopter Association International

1635 Prince St.
Alexandria, VA 22314
703-683-4745

International Wheelchair Aviators

P.O. Box 2799
Big Bear City, CA 92314
909-585-9663

National Association of Flight Instructors

P.O. Box 3086
Oshkosh, WI 54903
920-426-6801
www.nafinet.org

The Ninety-Nines

4300 Amelia Earhart Rd.
Oklahoma City, OK 73159
405-685-7969
www.ninety-nines.org

Soaring Society of America

P.O. Box 2100
Hobbs, NM 88241
505-392-1177

University Aviation Association

3410 Skyway Drive
Auburn, AL 36830
<http://uaa.auburn.edu>

U.S. Coast Guard Auxiliary

2100 Second St. SW
Washington, DC 20593
202-267-2229
www.uscg.mil

Women in Aviation International

3647 SR 503 South
West Alexandria, OH 45381
937-839-4647
www.wiai.org

Internet Resources

Embry-Riddle Aeronautical University
www.db.erau.edu

Federal Aviation Administration

www.faa.gov

Student Pilot Network

www.ufly.com

University of North Dakota

www.aero.und.nodak.edu

Western Michigan University

<http://avs.wmich.edu/index.html>

Flight instructors are either independent or associated with a flight school, and you can find both in the phone book and newspaper classified ads. The National Association of Flight Instructors lists its members in a searchable database on the Web at www.nafinet.org.

Flight training is regulated by Part 61 and Part 141 of the Federal Aviation Regulations. What's the difference between the two types of training? A Part 141 flight school's training plan specifies what students learn and the order in which they learn it. For full-time students, this structured plan makes for an efficient education and optimal use of time. Part 61, however, doesn't require schools to give lessons in any set order. This benefits part-time students, whose instructors can arrange the lessons as personal schedules and other factors, such as the weather, dictate. Regardless of the regulation a school follows, all pilots must learn the same material and skills, and everyone takes the same FAA tests.

Before enrolling at any school, interview the school officials and tour the facility. At some point, break away from your tour guide and talk to enrolled students; ask them about scheduling snafus, aircraft availability, and canceled lessons.

Look at the school's training aircraft. An oil-streaked airplane filled with trash that has several "Inoperative" placards stuck to instruments on the panel probably isn't one you'd want to learn in. Another bad sign: students who complain that they've had a number of lessons canceled because the airplane is "down for maintenance."

If you're pursuing an aviation career, where you learn to fly depends on your academic education. If you have a college degree, find a good flight school. If you don't have a degree—get one. Approximately 95 percent of the pilots airlines hire have a four-year degree. If you want to compete with them, you must have one too. A way to combine your academic and flight training is to attend a collegiate aviation program; you may qualify for financial aid and scholarships.

A number of colleges offer flight training to "civilians"—people not enrolled in a degree program. Western

Michigan University in Battle Creek, Michigan, is one. Other aviation colleges, such as Embry-Riddle Aeronautical University in Daytona Beach, Florida, and the University of North Dakota in Grand Forks, offer summer camps or academies that introduce teenagers to all that aviation has to offer and feature a lot of hands-on activities and tours. Often they include flight training, but not enough to earn a certificate.

The Solo

The most exhilarating (and maybe scariest) flight any pilot makes is his first solo—the day when the instructor jumps out and tells you to take off and land on your own. Your instructor knows you're ready because he approved this flight (so why isn't he in the airplane?). But you're not so sure.

When my turn came, one thought kept ricocheting inside my skull: *Can I do this?* But when I pushed the throttle forward to take off, my training took over, my self-confidence returned, and I flew—alone! It was more fun than any human should be allowed to have.

This was only the first of many highs that flying has given me over the past 24 years. There have also been a number of lows. Every student has them—learning plateaus, they're called. You're not getting any worse, but you're not getting any better either.

My first campout on the learning plateau happened while I was practicing landings. Consistency is the key to mastery, and for some reason I couldn't string together five good landings. I'd make two good ones, then bounce the next three. It was frustrating, but it taught me a lesson that has served me well ever since, and it had nothing to do with landings: Flying is a mental activity.

Don't believe me?

Don't think about a black dog!

What just popped into your mind?
A black dog, right?

Don't think about the black dog. Don't make a mistake. By thinking constantly about making a mistake, I was hindering my progress—something I couldn't see at the time. My instructor eventually saved me from myself with a simple distraction. Rather than watch me beat myself up practicing landings,

he told me to fly to a nearby airport for lunch—his treat. We had a nice flight, and I enjoyed employing my pilotage skills—that's navigating by comparing ground reference points you see from the air to the same references on your map. Because I was focused on our adventure (and lunch), I made a good landing. The five landings I made after lunch were just as good, and I soloed the next day.

Learning to land wasn't my last visit to the learning plateau, but the method of leaving it behind hasn't changed. Do something different—have fun! Whenever I feel a campout coming, I tell my instructor that I need to do something

different. Usually I practice a maneuver I haven't done for a while but know I can do. When I'm stuck on the plateau, doing something right always helps me get my bearings.

Fun is subjective, of course, so you have to find what works for you. What works for me is to talk to myself when I'm flying, regardless of who else is in the cockpit. With a tape recorder running, I critique myself and announce what I'm supposed to do next. How is this fun? When I listen to the tape later on, I always end up laughing at some of my expressions, and I learn from the mistakes I made. My instructor thinks I'm a little strange, but I usually



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Can You Afford It?

Several factors will affect the cost of your flying education: the pace at which you learn, weather, the cost of living in your area, fluctuating rates. But you can compute a ballpark figure with high and low estimates. During your interviews with instructors and schools, get prices for the following items (the amounts given are current estimates):

Basic Costs

- Medical exam—\$75
- Ground school—\$200
- Pilot supplies—\$100
- FAA knowledge test—\$50
- FAA practical test—\$150

Variable Costs

- Per-hour aircraft rental—\$70
- Per-hour instructor rate—\$30

The first five items, which total \$575, represent the base portion of your investment. Regardless of what kind of certificate you earn, these items are standard.

To compute the variable portion of your investment, add the hourly rates for your aircraft rental and instructor to determine the cost of one hour of flight training. For the example given, it's \$100 per flight hour. To figure your weekly investment, multiply this one-hour lesson fee by the number of times you plan to fly each week.

To estimate your total training investment to become a recreational pilot, multiply the hourly lesson rate by 45 hours, a reasonable amount of time for most people. Then add this amount to the basic costs for your total (see table below). If you're going for a private pilot certificate, and your schedule allows you to take five lessons a week, you can expect to spend around \$6,075 (see table below). If, on the other hand, you're a part-time flier who's taking a lesson once a week or so, your total investment will be much higher.

If your goal is a private pilot certificate but you are short on funds, it would be wise to first earn a recreational certificate, then add the training required to be a private pilot as time and finances allow. You'll need three blocks of additional training, and each has a three-hour minimum requirement (see table below).

Before you get too involved, take stock of your financial resources. In most cases, only students enrolled in a collegiate aviation degree program are eligible for financial aid and scholarships. Other students, however, may be able to get personal or home equity loans to help pay for their education.

Many flight schools offer discounts for buying flight time in blocks of so many hours. Another way to stay within your budget is to join a flying club. Most require dues, but they frequently offer lower rates.

	Total
Recreational Pilot Weekly Investment	\$100.00
Total Training Time	\$4,500.00
Fixed Costs	\$575.00
Total Training Investment	\$5,075.00

Cross-Country Add-On	\$300.00
Night Add-On	\$300.00
Basic Instruments Add-On	\$300.00
Private Pilot Checkride	\$150.00
Total Private Pilot Add-On Training	\$1,050.00
Private Pilot Through Add-On Training	\$6,125.00

Private Pilot Weekly Investment	\$500.00
Total Training Time	\$5,500.00
Fixed Costs	\$575.00
Total Training Investment	\$6,075.00



don't repeat the mistakes that end up on tape.

New challenges are fun too. Learning to fly a 1940-something Piper J-3 Cub was a hoot. You could fly the Cub with the door open, and that made it the perfect frame for the masterpieces painted by the setting sun on the Pacific coast in California. If I've learned anything about flying, it's that there is always something new to master. For me, flying will never be boring.

Time and Money

The cost of any new endeavor is an important consideration, of course, but just remember that learning to fly is an investment that could pay dividends for the rest of your life. And you can always add levels of knowledge and skill to the foundation laid by your original investment.

Flying schools rent airplanes by the flight hour, and they rent them "wet," which means the rate includes fuel. You pay for training one hour at a time—not in a lump sum. If you make a two-day trip someplace, you pay only for the hours of flight that you log, not how long the airplane is in your possession. (Multi-day rentals may have a minimum required flight time, such as two hours a day.)

Instructors also charge by the hour, and many have one rate for ground instruction and another for flight instruction. When visiting a flight school, you should get information about instructor and rental rates, as well as costs for textbooks, maps, flight computers, and other pilot accoutrements.

After you begin your flight training,

you'll find that you have some control over how much you'll have to spend (see "Can You Afford It?," on p. 68). The more quickly you learn the required material and skills, the smaller your investment. How quickly you learn depends on how often you fly, which of course depends on your schedule. Frequent practice is the best way to master any skill.

High Society

Although many people think of pilots as solitary individuals winging through the sky, flying is a social activity. It starts with your education, when you and other students spend many hours talking shop. There's also a virtual pilot community, the Student Pilot Network, in which students can share experiences and get answers to questions about training, flying adventures, and civilian and military careers (www.ufly.com).

To expand your aviation horizons even further, you can join a flying club. Or you can attend aviation gatherings small and large, from fly-in breakfasts to the annual AirVenture "family reunion" held by the Experimental Aircraft Association (www.eaa.org) each summer in Oshkosh, Wisconsin. If you attend AirVenture, you'll see more than 12,000 aircraft of all types and meet the pilots who fly them and others who are interested in all things aviation. EAA also has a nationwide network of more than 1,000 chapters, good places to socialize and learn about building, restoring, and flying airplanes.

The Aircraft Owners and Pilots Association, which publishes a monthly magazine called *Flight Training*, is another excellent source of new fly-

ing friends and information on everything from supporting local airports to what is entailed in owning an aircraft. Women in Aviation International and the Ninety-Nines are dedicated to increasing the number of female pilots. Both organizations have a network of chapters and scholarship programs.

If your airport has a control tower, call and ask for a tour. You can make the same request at any FAA air traffic control facility, where you can watch controllers working at radarscopes. Observing what goes on behind the scenes will give you a better understanding of how pilots and controllers work as a team to keep the skies safe.

You can use your new aviation skills to help others by flying for the Civil Air Patrol and the U.S. Coast Guard Auxiliary, which conduct search-and-recovery operations. Pilots who volunteer their services to the members of the Air Care Alliance fly patients to distant facilities for medical care (see "Center, This Is Compassion Seven-One-Golf," Feb./Mar. 2000).

Even if you're not flying, just hanging around the airport can be entertaining. You can learn something by talking with other pilots, and you never know when someone will offer you a ride. That's how I got hooked on aerobatics—the ultimate expression of flying's three-dimensional freedom.

The opportunities and possibilities aviation offers are as vast as the sky you'll fly in. —



Water Water Everywhere...

...and only a handful of helicopters to rescue victims of Mozambique's February floods.

Compiled from reports by Stam Predrag



AGENCE FRANCE PRESSE

Last January, unusually heavy rains began falling across much of southern Africa. The floods that followed claimed 70 lives by February 11, and it became clear that Mozambique, a nation on the continent's east coast, faced calamity. Rains falling in the Limpopo River basin upriver from Mozambique swelled the lower part until it overflowed its banks, eventually widening the Limpopo to five miles in places. On February 22, Cyclone Eline hit near the town of Beira, on the coast of Mozambique, with winds of 140 mph. Nearly a million people lost their homes.

On February 27, accumulating waters burst forth in the form of massive flash floods across the lowland provinces. A hundred thousand people were awash, some wading for miles in search of dry land, and another 7,000 survivors clinging to trees and rooftops where waters rose as high as 26 feet.

For Mozambique, the disaster was an enormous setback. The nation of 19 million gained its independence from Portugal in 1975 and immediately plunged into a civil war that cost a million lives. Since 1992, when a peace treaty was signed, its recovery has been a model for all of Africa. Mozambique reformed its economy, and in 1997 and '98 had one of the world's highest rates of growth. But when the floods came, farms, business enterprises, roads, and bridges were swept away as if the years of rebuilding had been only a dream.

In the floods of February 2000, economic concerns were set aside. There were tens of thousands to be rescued and no national assets to do the job. Mozambique's small helicopter fleet was mired in operations in distant African trouble spots, and its neighbors could offer little assistance.

In early February, a formal request for aid from the government of Mozambique to South Africa triggered an immediate tasking order to the South African National Defence Force (SANDF).

South African crews routinely lifted up to 60 people to safety in Oryx helicopters (left). Only an hour's flight away, South Africa had to go it alone until U.S. (right) and European flights arrived with needed supplies and equipment.

At 9 p.m. on the evening of February 10, authority was received at its Pretoria headquarters to mount a relief effort in the southern half of Mozambique. Two Mobile Air Operations Teams were placed under the command of Lieutenant Colonel Jaco Klopper, and by February 11, Operation Lichi was under way, based at the airport near Maputo, Mozambique's capital.

Although the international airport is equipped with a tower and navigation aids, for the relief missions afield pilots had to rely on satellite (GPS) navigation coupled to Doppler radar, which senses motion based on the frequency shift of the radar return. "Navigation was a bit of a problem initially," Klopper says. "People would say 'Go to this little town,' but with the whole area flooded, it was [a] purely GPS [operation]."

Klopper's fleet of aircraft included five Denel Oryx medium-lift helicopters, two Eurocopter-Kawasaki BK 117 light helicopters, and a mixed fixed-wing fleet of CASA 212s, a Cessna 208 Caravan, and a Cessna 185 Skyshout aircraft equipped with huge loudspeakers to pass messages to people on the ground. A local radio newsman provided the voice.

In the first two weeks, more than 7,000 people were rescued and more than 450 tons of food, medical supplies, blankets, and tents were deliv-

ered. Klopper describes the flying as arduous: "We flew from dawn to dusk, and poor visibility was the biggest problem—down to a quarter-mile in drizzle. And we knew there were up to 57 aircraft operating in the area at times, so congestion became a major worry."

The average South African helicopter is 10 years old—young compared to the U.S. rotary-wing fleet—and the teams were able to fly for eight or nine hours a day nonstop, standing down at between six and seven in the evening. Most work was performed in the open, with a hangar belonging to the local airline available if needed. With Pretoria only an hour's flight away, the teams brought along only a limited spares kit. Klopper says that most nights, maintenance crews were finished by nine o'clock. If any aircraft needed major work, it was swapped out with another from Pretoria.

"We had approximately one and a half crews for every aircraft, so we could fly for two days with a day off," says Klopper. "A number of copilots also doubled as cabin crew to help with loading evacuees."

Klopper says that crews asked their commanders for permission to fly up to eight and a half hours each day, although standard procedures state that only six hours per day is allowed. They also stopped counting "ferry time" to and from rescue sites and started the



ALEXANDER JOE/AGENCE FRANCE PRESSE



duty clock only once they commenced the actual rescue at a hover, which imposes the greatest concentration, stress, and consequent fatigue. At the peak of the operation, his crews flew four days in a row with a day off between shifts. On some missions an extra crew member flew along on his day off and rode the hoist down to rescue people.

"We had a major problem with the rooftop rescues in the [rotor] downwash," Klopper says. "Their belongings would be blown around, and the standard roofing is corrugated metal, some of it just held down with stones. When the corrugated metal starts flying, you have a high risk of damaging a blade." Klopper says one aircraft did suffer such an incident.

A Denel Oryx that would normally carry a load of 19 soldiers sometimes boarded as many as 60 passengers, "though many of them were children," Klopper says. Of the hundreds stranded in treetops, many were weak from hunger and dehydration—to say nothing of frightened by the helicopter. "In many instances, there was no time to use the hoist, so you simply flew the aircraft into the tree, pushed the branches aside with the belly until you could get close enough for them to board."

The Oryx is a twin-engine helicopter built in South Africa but based upon the French-designed Sud Aviation SA 330 Puma. Later it was reengined to Super Puma standard but retains the lighter, smaller airframe of the original. It normally carries a crew of three (pilot, copilot, and flight engineer) and is powered by twin Topaz turboshaft engines, locally built derivatives of the

French-designed Turbomeca Makila 1A1 driving four-blade semi-rigid rotors. For the rescue missions, the South Africans added a fourth crew member to assist people aboard.

The BK 117 is a follow-on to the German-designed Messerschmitt Bölkow-Blohm Bo-105 but with twin engines and a larger cabin. It employs a unique rigid rotor system in which the composite blades are mounted in a bearing-less rotor hub. When the controls are moved, the flexible blades twist in response, providing an exceptionally stable but responsive platform. It normally flies transport missions ferrying up to six passengers and carries a crew of two (pilot and flight engineer), but in Mozambique it often carried a third crew member in the cabin. The biggest load recorded by a BK 117 crew during the relief mission was 34 souls.

"At first we hesitated to deploy the 117s for rescue, but we found to our surprise that they performed quite well," Klopper says. "They have skids [for landing gear instead of wheels], and you could fly them right into the upper tree branches." Despite the haz-

Scanning the saturated ground for flood survivors, this Oryx crew member would fly dawn to dusk searching the devastated Chokwe area, about 125 miles north of the capital, Maputo (map above).

ards, the crews had only two minor incidents, one when roofing flew into a rotor blade and another when Klopper himself broke off a radio antenna on the belly while flying into foliage.

Klopper recalls one of the most hair-raising moments: "We discovered four children three to five years old who had scrambled to safety on top of a car's roof, and it was being swept down the river." Weak and exhausted, they were waiting for the helicopter to come, but a strong gust of wind from the helicopter's rotor knocked two of the kids into the water. "One of the crew members—a big guy—jumped out of the helicopter and managed to get hold of the two youngsters under one arm and the other pair under his other one. We got all four of them."

Klopper says that Oryx crews loaded while monitoring an instrument that indicates the pitch of the main rotor blades in degrees. The absolute maximum is 19.5 degrees, at which point the blades may stall. "We would keep loading at 14 point five, maybe 14 and three quarters," Klopper says. "Then at 15 we'd say 'Stop.'"

Captain Chris Berlyn and his three-man helicopter crew may have helped galvanize the international community to speed up aid for Mozambique. On March 1 Berlyn and his crew saved a young mother, Sophia Pedro, and her newborn baby (later named Rositha)





When they had time, Oryx crews used hoists to lift victims aboard; when time was short, they simply flew into the trees to get the victims.

Britain, and Germany by mid-April, and the World Food Program had taken over. The fleet had numbered 60-odd aircraft at the height of the operation in March, but it is now half that.

Not everything is going smoothly: Wilfried De Brouwer, chief of a joint logistics operation center supporting relief flights, reported that the theft of jet fuel threatened the continued operation of relief aircraft. Officials surmised that the fuel was being stolen to fill diesel-powered cars and trucks.

One controversy persists: Why the delay before international help arrived? It took over three weeks to rouse the international community, including the United Nations. Graca Machel, the widow of Mozambique's first president, Samora Machel, and wife of the former South African president, Nelson Mandela, did not hesitate to pose this question to the world. In an interview with the South African media, she said, "There'll always be a question why it took so long....When we are dying in the thousands, then they come running. It's always too late." Calls for a regional body to coordinate relief efforts in southern Africa have resulted in meetings but no firm plans—yet.

The Mozambique saga proves that the South African military has undergone drastic changes since the end of apartheid in 1994. Many pilots who once served the country's former white minority regime flying combat missions in neighboring countries risked their lives in Mozambique to save black men, women, and children. When he was asked about this, Jaco Klopper, a white South African, said, "We live in the future, not the past."

A woman who was rescued told a reporter, "These men deserve to go straight to heaven." And an e-mail addressed to the SANDF headquarters in Pretoria said the following: "Hello, I am just an ordinary citizen.... I can truthfully say that for every life saved in Mozambique by these talented pilots, they helped heal not only the life they were saving but many old wounds in many hearts." 

from a tree. The picture was broadcast around the world, and millions of people watching suddenly realized the extent of the tragedy. Shortly thereafter aid began to arrive from the United States under Operation Atlas Response, the first elements of which landed on March 5.

Before the rains let up and the waters began to recede, some 700 people had died as a direct result of the floods. By March 6, when the SANDF rescue flights ended, the South African crews—who kept meticulous daily records—had rescued 14,391 people. By April 18,

they had moved more than 2,273 tons of relief supplies and delivered 1,167 drums of fuel, flying a total of 2,035 hours.

More grim data: At least 345,935 acres of prime farmland, the livelihood of some 123,000 families, was lost. Close to a million people were affected by the floods, and many of them lost their homes, while the total damages are believed to run in the hundreds of millions of dollars.

Most of the military aircraft flying in support of the relief operation had returned to the United States, France,

Should NASA Sell Ads? | by Bob Garfield

Before answering, we should admit how much we allow commercials to intrude in our lives.

You probably know the joke: At a party, a wizened old tycoon approaches a curvaceous blonde. "If I gave you a check for \$5 million," he asks her, "would you sleep with me tonight?" She looks at him, stunned. He's a revolting specimen, but five million bucks would take care of her sick parents and set her up for life. "All right," she replies, gulping. "I'll do it." Thereupon the old guy hands her a \$5 bill and starts to lead her away. "Five dollars!" she cries. "What do you think I am?!" The old man glowers at her: "We've established what you are. At this point we're just haggling over price."

Now then, about the space program...

So NASA is preparing to lease parts of the International Space Station and associated missions to private interests. And the space agency is even considering making itself available to advertisers—advertisers!—for brand promotion and who knows what else. And that all seems so unsavory, so indecent, so corrupt. First they're launching commercial satellites, then maybe subletting square footage in the space station to, say, Intel (\$20.8 million per "site bundle"), then—what?—Tang commercials in orbit? Ugh. There are some things you just don't do for money, because once you do, you have established what you are, and thereafter it's just talking price.

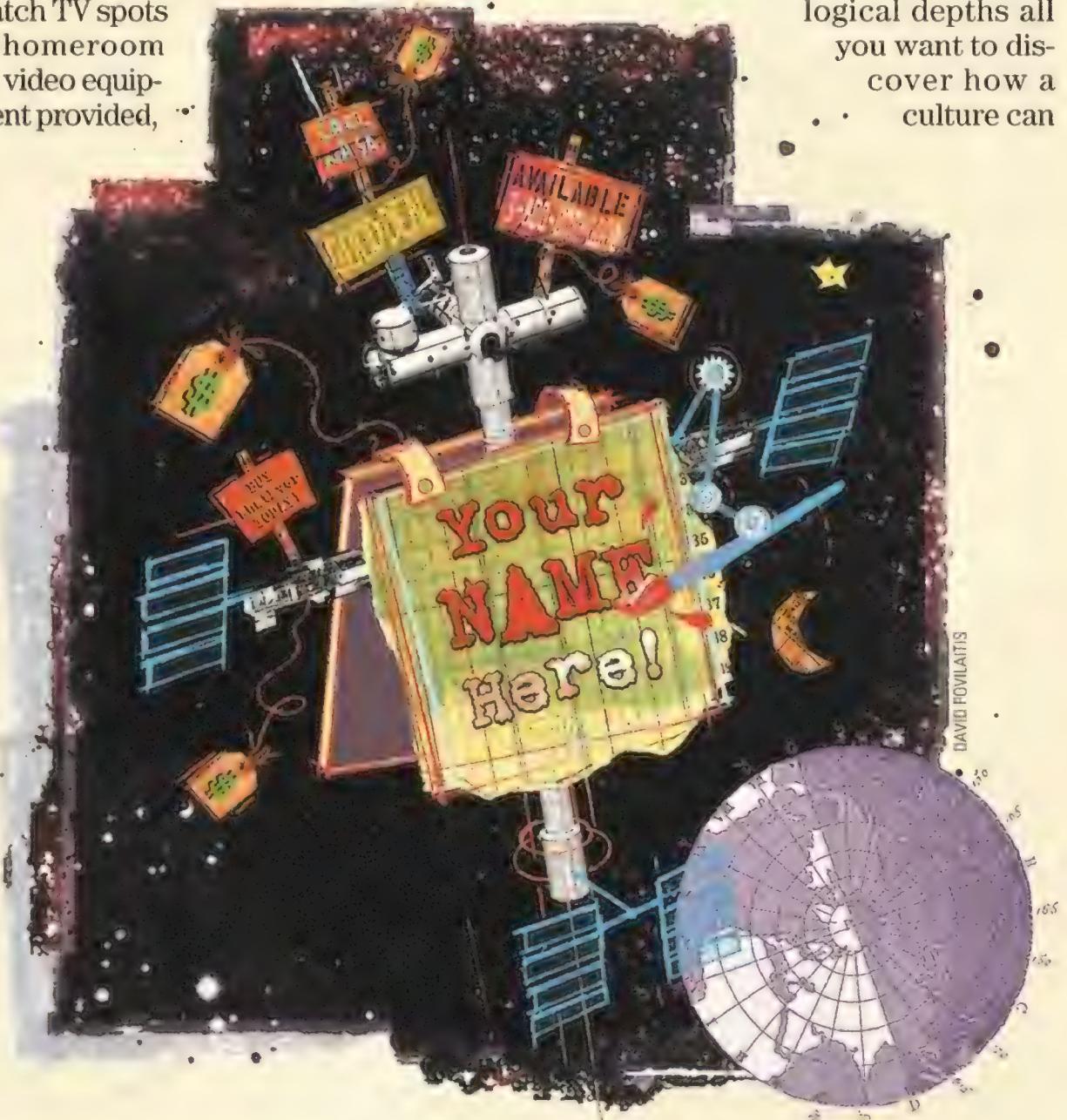
Yessiree, it's easy to approach NASA's flirtation with commercialism with raised eyebrows and the sort of scorn we tend to heap on the morally inferior. But before we start condemning the space agency for even thinking about prostituting itself, perhaps we ought to get in touch with our own inner whores.

We the people, I'm talking about.

We who endure television commercials because we get the programming for free. There's no way to know what pay TV would fetch for "ER" or "60 Minutes" or "The World's Most Infected Animal Bites" or whatever, but no doubt the tariff would be steep. So we sit through the spots for Correctol and HeadingForChapterXI.com pretty much without complaint. Likewise, we suffer Internet billboard ads, because we get Web content for free. We let our kids watch TV spots in homeroom on video equipment provided,

gratis, by our good friends at Channel 1. Many people are letting their private long-distance phone calls be interrupted by ads in exchange for toll-free conversation. With lesser degrees of acquiescence, we get pummeled by advertising in the supermarket, at the gas pump, on the golf course, in the bus, at the beach, and—in a most peculiar exercise of mutually indecent exposure—at the barroom urinal.

That's because as a society, we've long since demonstrated that we will accept, even embrace, advertising messages almost anywhere, provided there's an acceptable quid pro quo. And there's not a thing wrong with that. You can plumb the anthropological depths all you want to discover how a culture can



Commercialism

so blithely surrender its peace and quiet, to say nothing of privacy, in exchange for "Baywatch." You can rail against the environmental evils of the consumer society and advertising's incendiary role within it. And you can certainly excoriate a large percentage of the ads themselves for breathtaking stupidity. The fact remains, however, that the American people, in their media consumption and their mortgage payments alike, are accustomed to being subsidized.

Sure, it is a deal with the devil, and one need only look at the programming on commercial TV to see that the devil's got the upper hand. But it's a deal we made long ago, with our eyes wide open. Truly, it is the American way. So at a time when the balanced federal budget has imposed austerity across the board, why wouldn't NASA want to benefit the same way—i.e., by subsidizing the taxpayers' share of space exploration with a reasonable percentage of commercial revenue?

This is precisely the question posed by Mark Uhran, director of the agency's Space Utilization and Product Development division. "The way I look at it," Uhran says, "it's not just a case of saving money. We could increase the capability of the space station without having to return to the Congress for further appropriations."

For instance, Uhran supposes, what if NASA wanted a telecommunications upgrade for the station that wasn't budgeted? Instead of going back to the appropriations committee hat in hand, the agency could tap its reservoir of commercially generated revenue. The commercial partners would be happy. Congress would be happy. The telecom contractors would be happy. The astronauts and mission control would be happy.

"A win-win situation," he says.

Moreover, adds Uhran, because NASA understands the road to commercial-

ism is a slippery slope (e.g., Jerry Springer), all involved will take great care in selecting commercial partners and limiting the scope of the partnerships. "We don't want to do anything to compromise NASA's image," Uhran says, "and we *won't* do anything to compromise NASA's image."

That sounds like a guarantee to me. So if Candlestick Park can become 3Com Park, and if half of America will sit through a six-hour, high-pressure time-share harangue in exchange for an off-season weekend at a crappy resort, and if millions of people commit

It's easy to approach NASA's flirtation with commercialism with the sort of scorn we heap on the morally inferior.

to three expensive years of Compuserve to buy down \$400 on a new computer, why should the National Aeronautics and Space Administration be held to a different standard?

Answer: Because it is the National Aeronautics and Space Administration. Because in an era in which government agencies are held in contempt by a skeptical, cynical public, NASA stands virtually alone in the public's trust and esteem. Because in an era that is short on non-basketball-playing heroes, NASA astronauts are living icons. Because NASA, in dispatching these icons into space at their substantial peril, should be held to a higher standard.

Because no amount of revenue can ever repurchase your dignity, and if it starts lending its name to fast food chains or even software companies,

dignity is what NASA would lose first. If Charlie Sheen won't do a commercial in America, for crying out loud, why in the world would NASA?

The reason the agency is so cautious and conflicted on this subject is because the question isn't how prudent explorations of commercialism might help the space program. The question is how they might destroy it. For starters, prudent explorations, once they begin generating cash, will quickly lead to imprudent explorations. When commerce drives decision-making in any way, shape, or form, how long will it take before commercial partners start throwing their \$20.8 million "site bundle" weight around?

In fact, it doesn't matter if the piper is calling the tune or not. The public, which, as we have seen, is experienced in these matters, will assume the piper is calling the tune, and that presumption of prostitution will rob NASA of its most precious asset: the faith of the people. That faith was shaken after the *Challenger* explosion. It is fragile still.

So let's think back a moment. Fifteen years ago, NASA flew a Carbonated Beverage Dispenser Evaluation "experiment" aboard the space shuttle, prominently displaying cans of Pepsi and Coke. Two years later came the *Challenger* tragedy.

Now suppose it had been the *Challenger*'s mission to test soft drinks, and seven astronauts were martyred to that cause. "I don't even want to imagine that," Mark Uhran says.

What NASA should do is imagine it—every time some tycoon makes an offer that looks too good to refuse. Then it should smile politely and walk away. Because spaceflight sponsorship isn't TV sponsorship, and the price is simply not the point. 

Bob Garfield is a columnist for *Advertising Age*.

Bomb Squad

by James Schultz

How airborne detectives collect evidence from a cloud of atomic debris.



Mavigator Jimmie Riley fondly remembers a mission when he could smell popcorn all the way to the cockpit. More frequently, there are the aromas of fresh-baked pizza and the unmistakable scents of TV dinners, baking slow and steady, the old-fashioned way. You got a stove, you use it, Riley says—even if you're 30,000 feet up and especially when you've been flying 15 hours straight. Long missions are the standard for Riley and his many crewmates. He navigates one of the last remaining WC-135s equipped for Constant Phoenix, the nation's only airborne program to detect nuclear fallout. It's a mission that takes Riley all over the world to retrieve evidence from the area of a nuclear explosion.

In early May 1998, the WC-135s were only days away from administrative death. Escalating maintenance and repair costs for the aging aircraft (today, two survivors of a sampling fleet that in its heyday numbered more than six dozen) had convinced the Phoenix program's managers at the Air Force Technical Applications Center just south of Cocoa Beach, Florida, to ground the 135s while the center developed a modular system of sensors that could be plugged in and flown on any cargo-type aircraft. AFTAC operates the U.S. Atomic Energy Detection System, a global network of nuclear blast detectors that includes, in addition to the aircraft, seismometers, undersea listening devices, and satellite-mounted optical sensors calibrated to detect the flash of an above-ground atomic explosion. There hasn't been an above-ground test since 1980, when China detonated two bombs in the atmosphere.

"By 1997, the debate was: Should we continue to fund this aircraft, which needed major maintenance, or not fund it and take the risk that it wouldn't be needed?" says David O'Brien, AFTAC chief scientist. "The decision was made not to fund the maintenance.... We

An RB-57 with detection pods under its wings sniffs the air near a Stateside nuclear test. Many aircraft have flown such Constant Phoenix missions since 1947—pilot Marc Lynch does the job today in a WC-135 (right).

thought we could live with a gap."

The answer seemed clear. In addition to waiting for enhanced grab-and-go airborne sampling equipment, policy-makers put their money on pending advances in remote sensing technology, hoping that the Phoenix aircraft, sometimes called "Sniffers," would enjoy a quiet retirement—an approach that appeared to be the best option given a tight budget.

The equation suddenly changed over two weeks in May 1998. In rapid succession, India and Pakistan set off nuclear explosions in underground test chambers. "At the 11th hour and 59th



minute something happened," O'Brien says. "If India and Pakistan hadn't occurred, that aircraft would be retired and sitting in the desert outside Tucson, Arizona."

The two main benefits of airborne sampling—mobility and pinpoint retrieval of debris—kept the Sniffer in business. "If you have a ground sampler at a forward location, you'll collect effluent if the wind is kind to you," O'Brien says. "We have sensors around the world to detect the blast. We do air mass projections and put the plane where there is radioactive xenon [the telltale sign of a nuclear blast], which has a short decay life."

Xenon radionuclides exist in minute parts-per-trillion concentrations after a blast, and can be detected only by sampling. Seismic or space-based detection can determine only that a test has taken place and cannot provide detailed information about the weapon's technology. Airborne sampling is actually the retrieval of microscopic pieces of the bomb itself, which are subjected to radiochemistry to analyze the materials used. "There's nothing [else that] can do what that aircraft does," says Lieutenant Colonel Steven Nachtwey, 45th Reconnaissance Squadron commander. "[Constant Phoenix] is an extremely valuable program that provides hard evidence to decision-makers."

In addition to improving its airborne capability through Sniffer upgrades, AFTAC is developing an enhanced network of automated, ground-based samplers that will collect and analyze air in place and send the results over high-speed, secure networks. But such devices, no matter how sophisticated or robust, are vulnerable. Friendly governments can fall, replaced by hostile ones. Sabotage occurs. Accidents happen. By the time the air mass reaches samplers on the ground, traces of xenon could already have disappeared. What guarantees against such failures is redundancy, in a geopolitical environment that remains unpredictable, even with the much touted safety that the end of the cold war was supposed to bring. The key to detection remains flexibility.

"You have a finite number of assets. You have to deploy them prudently as events occur," says Cargill Hall, chief

USAF/SENIOR AIRMAN DELANIE STAFFORD; OPPOSITE—CHUCK HANSON



chemical signatures of radioactive particles at a distance. If detonation occurs underground, sensitive seismometers track the signatures of acoustic pressure waves rippling through Earth's crust, while underwater hydrophones can "hear" the distinctive after-blast sound that can carry for thousands of miles through the world's oceans.

When the notice is given, aircraft maintainers in Nebraska run through the preflight checklist while the aircrews hustle from Patrick to Orlando International Airport, an hour's drive, to catch the first available commercial flight to Omaha. Once they land, it will be another half-hour drive down the interstate to Offutt, and takeoff in the waiting WC-135.

Inside a Sniffer as it flies toward the location of a recent detonation, as more than 30 crew members may be on board, including three pilots, two navigators, one deployment commander, a mission commander (who supervises the running of the Phoenix's atmospheric sampling gear), as many as three special equipment operators (SEOs), three atmospheric technicians, and some 18 maintainers who will work on the airplane when it sets down. Once airborne, directed by sensor data and constantly updated weather forecasts, the WC heads for the fallout plume and hours of sampling. It can fly the better part of a day before it arrives at the location of a blast and begins the methodical tracks that will take it through whatever airborne fallout awaits. Landings are required every 24 hours to allow the crew to rest and to unload samples that have to get to laboratories for fast analysis.

"Those 18- to 20-hour missions are a killer," says Technical Sergeant Richard Bohn, an SEO. "You're just transiting, flying along fat, dumb, and happy. It's lots of boredom followed by lots more boredom."

In flight, a senior SEO sits at an equipment console roughly the size of two large filing cabinets. The console is electrically connected to four externally mounted Geiger-Müller tubes that watch for the presence of gamma radiation.

The WC must remain outside national boundaries, in international airspace, a task made far easier by the

The United States conducted dozens of nuclear trials during the 1950s. Ground crew wash down a B-29 at a Nevada air base after it penetrated a fallout cloud in 1952 (above). The Air Force also used QF-80 drones with wingtip samplers (right).

historian in the National Reconnaissance Office in Chantilly, Virginia. "What Constant Phoenix provides is definite confirmation of an above-ground test, or a leak from underground testing. Sniffer aircraft are a vital element of any strategic reconnaissance program."

On a blustery January day this year, a WC-135 sat on the ramp at Offutt Air Force Base in Nebraska, bright afternoon sun playing over its fresh coat of white and blue paint. (Even though AFTAC oversees the Constant Phoenix mission, the Air Force's Air Combat Command at Offutt has operational responsibility for the WC-135 airframe.) Riley, a captain in the 45th Reconnaissance Squadron, shepherded visitors through a quick tour of the aircraft, which had just returned from an exhaustive, months-long refurbishing in Greenville, Texas. For the 39-year-old airplane, it was not just a minor facelift. The WC was stripped down to skin and struts and put back together, panel by panel, rivet by rivet. Wiring by the mile was checked or replaced and some key avionics systems upgraded: There's a new digital altimeter and souped-up navigation system with enhanced Global Positioning System capability. Outside, Air Force maintainers



braved wind chills in the teens as they checked engines and landing gear, while inside, a cockpit electronics check was in progress. Sound-deadening carpet arrived for reinstallation. This WC, once ready for retirement, was again ready for the call.

The Sniffer is scrambled when any of the worldwide network of AFTAC sensors detects a nuclear blast and the Joint Chiefs of Staff at the Pentagon give the final go-ahead for flight. Data from a combination of orbiting satellites and ground and undersea sensors is funneled to AFTAC headquarters at Patrick Air Force Base in Florida. The triad works in combination, each part supporting the others. If a detonation is above ground, satellite-borne sensors can distinguish between the optical signature of conventional explosives and the flash of nuclear ordnance. Other detectors mounted on satellites discern post-detonation gamma rays at high altitudes, observe slight atomic-blast-induced fluctuations that disturb Earth's magnetic field, and monitor

latest generation of navigational aids. "We have to know our location at all times," says Riley. "When we say we know where we are, we know where we are. We don't want to violate anyone's airspace."

The Sniffer's array of sampling apparatus includes filter assemblies, large-pizza-size disks that rotate from an interior storage mechanism into twin fairings—known as U-1 foils—mounted mid-fuselage over either wing.



USAF/SENIOR AIRMAN DELANIE STAFFORD

The assemblies, made from cotton-based filter paper with a gauze backing, trap particulates like dust, dirt, and the byproducts of fissionable material down to micrometer size and lower—mainly the debris that would linger from an above-ground nuclear test. Before opening the U-1 foil's pneumatic clam-shell door, a console operator slides the filters one by one into position to face the onrushing airstream, as a jukebox might ready an oversized record for

Today, the WC-135 (bottom) has been overhauled to provide on-the-spot verification of a nuclear test. Over-wing scoops (left) direct air through the U-1 system, the heart of which is a set of 12 filter disks (below) for trapping radioactive particles. After the aircraft lands, the disks are hustled off for analysis.



WILLIAM B. SCOTT/AW&ST



play if the turntable were vertical instead of horizontal.

As the foils sit in place, any particle with ionizing radiation that strikes the surface is sensed by the Geiger-Müller tubes, which send an electrical signal to the SEO's equipment. Increasing radiation detected means that particles are building up on the foil, and that the aircraft is indeed flying through a radioactive cloud from a nuclear blast.

When such levels are detected, SEOs often direct the pilot to start a left or right orbit to remain inside the cloud. If radiation levels continue to rise, the orbit is continued while filter foils are changed, usually every hour or so. Whenever rain threatens to dilute or wash away a particulate collection, the filters are retrieved. In addition, operators must be aware of effluent from volcanic eruptions, the dust from which contains naturally occurring radioactivity that could contaminate samples.

The Sniffer also carries 40-pound air collection spheres, and handling them is the hardest and potentially the most dangerous part of the mission. Run off a quartet of compressors, the spheres collect and confine air that could contain trace signs of underground nuclear tests. "Unless someone violates the old [test ban] treaties, you won't get solid debris," says AFTAC's O'Brien. "If you get debris at all, it's probably in gaseous form."

Since there are only four compressors but as many as 44 spheres on a given flight, the stainless steel containers have to be regularly swapped out. Once unbolted from a compressor, an air-containing sphere is stored on a nearby rack, while an empty one is attached to the compressor line, a process known as "throwing spheres." Sometimes when the ride gets bumpy, that is exactly what happens. "I hit the ceiling once with two spheres in my hand," Bohn says. "I thought, *We hit an air pocket*. Then I thought, *This is not a good thing*. When we bottomed out, I was on the floor." Fortunately for Bohn, no permanent damage was done.

Depending on takeoff and estimated arrival time, technicians, SEOs, and maintainers catch some shut eye, bunking down wherever there's space. Bunk beds are aft, and there's that

padded carpet—for insulation and noise abatement—for those who prefer to stretch out on the floor. Because of prevailing global air circulation, the WC often finds itself 20 degrees north or south of the equator, usually flying at relatively low altitudes to enable effective sampling. That often makes for a bumpy, hot ride. "Often you'll be flying through clouds at 3,000 feet," says Phoenix co-pilot Marc Lynch. "It's an uneasy feeling when you can't see the ground," navigator Jimmie Riley says. "Tension definitely increases. You can hit some rough weather and get boxed in. You look for where the hard [thunderstorm] cells are and try to avoid them."

Because air sampling compressors run constantly and throw off heat, temperatures inside the fuselage can blossom to equatorial levels, despite the best efforts of the aircraft's air conditioning system. To provide temporary relief, WC pilots will often "cold soak" the aircraft by climbing up to 30,000 feet, with heaters off and crew bundled up, and direct the outside sub-freezing air inside. Then it's back down to altitude, and to business.

Once collected, air and filter samples are stored. After the WC lands—almost always at a military base—technicians, SEOs, and maintainers pitch in to off-load the samples and put them into another transport, which will fly them Stateside. "You've got a very perishable commodity," says Doris Bruner, chief of the AFTAC atmospheric test branch. "Those little radioisotopes can decay quickly. You try to get into position as quickly as you can for collection and then back to the laboratory for analysis."

Bohn, a 10-year Constant Phoenix veteran, says that once a bomb goes off somewhere on the globe, crew members can forget any scheduled weekend getaways, chores, or time with the family. For Bohn, a fervid Florida volleyballer, it might be a long time before he's back on the beach. "It seems like [missions] usually happen on Friday afternoons before a holiday or a three-day weekend," he says. "But as soon as the balloon goes up, we're gone. In 30 minutes my bag is packed and I'm ready. I keep a bag for summer and I keep a bag for winter. If there's a



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WILLIAM B. SCOTT/AW&ST

Air samples collected in spheres (top) are tested on the ground for radioactive xenon gas, a sign of a nuclear detonation. Special equipment operators (above) direct the WC-135's pilots to keep the aircraft in the debris cloud.

possibility that we'll be seeing both hot and cold weather, I bring both."

"It tightens everybody up when you get the call," says Lynch. "You sit back and think *What are we going to fly into?* The Phoenix missions are long and they're sudden. You go and for the next week you're going to live in that airplane."

The Sniffer is continuing work begun on September 16, 1947, when then General Dwight Eisenhower assigned the Air Force the responsibility for

detection of atomic explosions worldwide. By the close of 1948, 55 filter-equipped RB-29 Air Weather Service aircraft were flying frequent sampling missions from Guam to the North Pole. A year later, on September 3, 1949, an RB-29 flying between Alaska and Japan detected what the entire fleet had been searching for: debris suspected to be from a Soviet atomic test. Confirmation came with 92 flights that collected 500 air samples in a two-week period. In a national radio address on September 23, President Harry Truman announced that the United States was no longer the planet's sole possessor of nuclear weapons.

By July 1950, equipment aboard Constant Phoenix aircraft was capable of collecting air samples at altitudes ranging from 1,000 to 30,000 feet and quickly returning them to ground-based laboratories for analysis. By 1953, monitoring techniques improved with the addition of compressors and spherical containers that could hold more sampled air under higher pressure. A decade later, just prior to the signing of the Limited Test Ban Treaty, sampling reached its peak, as 77 airplanes—including B-52s and U-2s—regularly scrambled from nine airfields, covering roughly two-thirds of Northern Hemisphere airspace. By December 1965, WC-135s had taken the stage as the newest addition to the Constant Phoenix fleet. These were the aircraft flying in 1995 when both France and China conducted underground tests. Even when a nation admits to testing a nuclear device, the aircraft are sent to search for possible leaks of radioactive debris.

For crew members used to the cramped confines of earlier aircraft, the WC's 136-foot-long, 12-foot-wide size was a relief, with plenty of walk-around space and legroom to spare. Inside, improvements to air-sampling equipment made it easier to collect evidence of fallout and to preserve it for laboratory analysis. The aircraft could operate for longer periods of time; extended-range versions capable of being refueled in flight appeared in 1968. Sampling missions were routinely conducted over the poles, the Far East, the Indian Ocean, the Bay of Bengal, and the Mediterranean Sea, as well as

Pakistani demonstrators rejoice in 1998 (below) after their nation detonated five nuclear weapons in answer to India's tests. Until those bombs went off, WC-135 Constant Phoenix aircraft (right) were headed for retirement.

off the coasts of South America and Africa.

Phoenix equipment on board the WC-135 seems straight from the 1960s: consoles made of painted steel with analog gauges and dials. In fact, concedes Doris Bruner, Constant Phoenix equipment has changed very little since then: "There have not been a lot of technology improvements. We're working at the limits of detection."

But when the new gear for the Constant Phoenix program is completed, it will grab the first available seat. No longer will Constant Phoenix be "tail designation specific," limited to flying on a single airplane. In a sense, the program will eventually return to its glory days, when dozens of aircraft were involved in sampling missions. To boost portability, the sampling system will be plug-and-play, with simple on/off switches and direct electrical connections to onboard power supplies. To avoid cutting holes in airframes, engineers at AFTAC are considering modified aircraft doors. Particulate collectors could be affixed to the doors, which could then be installed on the aircraft selected for



the next mission. Although in theory the system could be put on several different kinds of aircraft, managers are now eyeing the current fleet of KC-135s and C-135s, as well as the two WC-135s also used. "We want to get away from the concept of one, two, or three airplanes," says O'Brien. "We want to be able to pick up the phone and fly a mission right away. Whatever [aircraft] is ready, we load our equipment and off we go."

The current WC-135 Sniffer aircraft are, despite advanced age, sturdy and reliable, but they require constant vigilance nevertheless. Concerns about encroaching on foreign airspace mandate flights over water, requiring the 45th Reconnaissance Squadron to adhere to an aggressive program to

control corrosion. Every day technicians inspect all parts of the aircraft, including engines, hydraulic systems, and control surfaces, to catch corrosion in the earliest stages. The sampling technology may not have changed much since the 1960s, but with upgrades to the airframe, the WC-135 has actually become more reliable. "Thanks to its advanced avionics and improved technology, it's doing its job better than ever," says Technical Sergeant Frank Morales, a maintainer who has worked on the WC since 1986. "It's amazing this 135 has gone through the transitions it has." Morales reports that, with the exception of certain stretches of old and brittle wiring and the occasional hydraulic leak that occurs as seals stiffen in cold weather, there is no single WC-135 component that requires repeated monitoring and replacement.

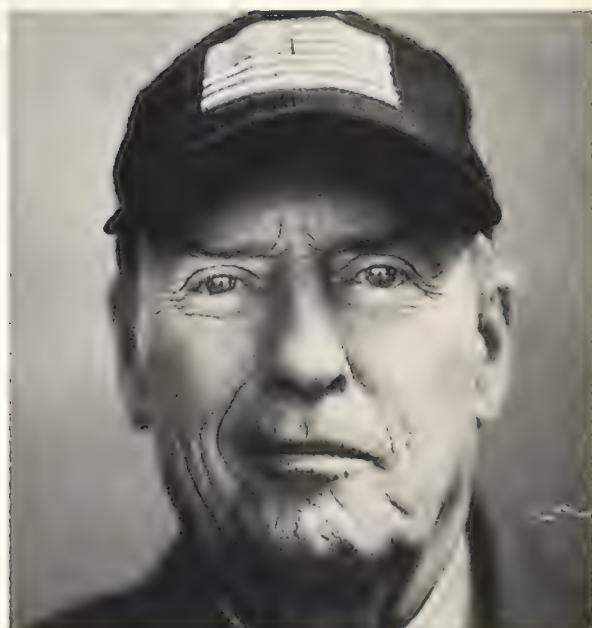
Despite the Sniffer's hardiness, money is what lifts its wings. The Constant Phoenix annual operating budget stands at \$2.3 million, a pittance compared to expected and enormously expensive upgrades. So budget planners don't see a realistic prospect of continuing the program as is. "The big rock in the road is the \$29 million that we'll need to re-engine the WC in 2003," says Charles McBrearty, AFTAC director of materials technology. "There won't be buckets of money rolling in. That's why we're planning now."

Constant Phoenix was a creature of the cold war, born and bred because of superpower rivalries and threats to political stability. Ironically, the unpredictability of the post-cold-war world may be what ensures its survival.



AP PHOTO/K. M. CHAUDHRY

►SIGHTINGS◀



PHOTOGRAPH BY MICHAEL O'NEILL FOR VANITY FAIR/CORBIS OUTLINE

Astronaut John Glenn's return to space in October 1998 caused a surge of interest in NASA's Mercury, Gemini, and Apollo pioneers. It also paved the way for a number of public astronaut reunions that continued through the Apollo 11 anniversary celebrations the following year. But photographer Michael O'Neill wanted to get the astronauts before the media descended *en masse*, so in July 1998 he orchestrated several sessions with the space heroes, both in groups and individually. He met Pete Conrad (above), a Gemini, Apollo, and Skylab astronaut who died in July 1999, at the Rosamond dry lake bed at Edwards Air Force Base, California, and caught Mercury 7 astronaut Scott Carpenter at the Brooklyn Piers in Brooklyn, New York (left). O'Neill, whose other astronaut portraits appeared in the October 1998 issue of *Vanity Fair*, also met up with an enthusiastic quartet in Dayton, Ohio. Mercury through Apollo astronaut Wally Schirra; Apollo 8 commander Frank Borman; Gemini, Apollo, and Apollo-Soyuz veteran Tom Stafford; and Apollo 13 commander Jim Lovell (opposite, left to right) were there for Lovell's induction into the National Aviation Hall of Fame.





Paper Airplanes

Looping the Loop: Posters of Flight

by Henry Serrano Villard and Willis M. Allen Jr. Kales Press (760-431-0282), 2000. 160 pp., \$40.00.

Even as daring aeronauts ascended in balloons, the Wright brothers flew at Kitty Hawk, and Lindbergh crossed the Atlantic, poster artists chronicled the emerging importance of aviation with brushes, charcoals, and pastels.

Looping the Loop is a rich collection of their work that spans the period between the late 19th century and World War II. The compilation highlights 102 posters, including 32 on display until July 9 in a companion exhibition at the National Air and Space Museum, all from co-author Willis "Bill" Allen's extensive collection of aviation memorabilia.

The book is a collaboration between Allen and Henry Serrano Villard, a career diplomat, author, and early flight scholar who died in 1996 at the age of 95. Villard wrote *Contact: The Story of the Early Birds*, and wrote the detailed descriptions that accompany each poster reproduction. He brought a unique perspective to the book, having experienced many of the events chronicled in the posters firsthand, including air exhibitions and races. His text adds greatly to the reader's understanding of the art, especially the earliest works. Many of the posters are extraordinarily beautiful, but without context and translation, they would be harder to appreciate.

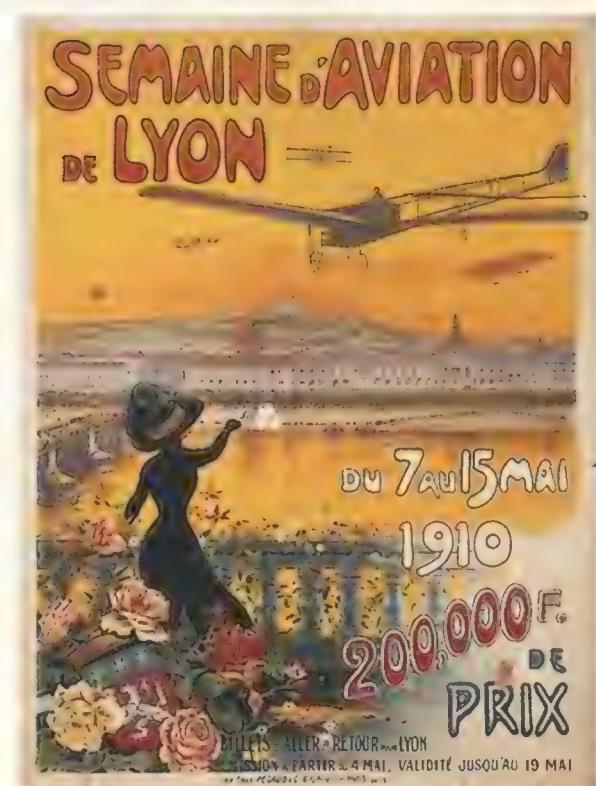
Villard provides the background for a fanciful—and wildly colorful—poster announcing one of the first large-scale flying competitions held in the United States, in which Glenn Curtiss and fliers from his school competed against noted French aviator Louis Paulhan in 1910. Villard pokes gentle fun at the event's promoters, then introduces the overheated ad copy they used to promote the event: "Under blue skies, the atmosphere laden with the perfume

of flowers and the scent of orange blossoms, Los Angeles has added the most lustrous jewel to her diadem of world fame...the only place...where in the month of January the atmosphere is balmy, light, and warm enough for...a successful meet."

The posters in the book—from the collections of Allen and other enthusiasts—are beautifully reproduced. The unknown artist who publicized a week-long flying demonstration held in 1908 by famous early aviator Henry Farman (right, below) illustrated a Voisin pusher—Europe's first standardized and practical airplane—flying above Gent, Belgium. On another page, Lyons, France (right, above), the center of a 1910 flying competition, glows warmly in evening light. The Lyons fly-in attracted several leading aviators of the day, including Hubert Latham, Charles Van den Born, Louis Paulhan, and Georges Chavez, who all competed for a prize of 200,000 francs. The poster includes a common image seen throughout both the book and the exhibition: a glamorous woman waving to gallant aviators overhead—what Villard called "the undisguised admiration of the fair sex for heroes of the air."

Other favorites include World War I posters imploring viewers to "join the Air Service," airshow ads offering parking for 25 cents and autogyro rides for a buck, and a World War II plea to follow in the spirit of wartime hero Jimmy Doolittle; the poster, which marries inspirational artwork with yet another copywriting gem, entreats citizens to "do more for Doolittle."

Looping the Loop is a wonderful tribute to aviation's colorful first half-century.
—John Sotham is an associate editor of Air & Space.



Carl Sagan: A Life in the Cosmos

by William Poundstone. Henry Holt and Company, 1999. \$30.00 (hardbound).



Among the general public, Carl Sagan will forever be remembered for "Cosmos," the 13-hour 1980 public television documentary series that made him a star and, to no small degree, made science understandable, if not cool. Among scientists—Sagan's professional colleagues—he will always be remembered for, well, "Cosmos."

The catch is that both groups perceived Sagan and his work quite differently. Instead of seeing him as a thoughtful educator in fashionable black turtlenecks, as the public did, his fellow scientists saw him mostly as a mere "popularizer"—and to a considerable degree they hated him for it.

This is the thrust of William Poundstone's excellent biography. Though Sagan, who died in 1996, was a gifted and prolific scientist who was making significant contributions to NASA's solar system exploration efforts years before "Cosmos" went into production, he always struggled, albeit quietly and gracefully, to come to terms with contemptuous and dismissive assessments of his life's work. At one point, many of Sagan's ideas began to be rejected simply because of their source. The unkindest cut of all came when his nomination for membership in the National Academy of Sciences was rejected. One member later commented that if it were not for "Cosmos," Sagan

would have been accepted.

Poundstone's thoroughly researched and well-crafted assessments of these and other episodes is even-handed. In the case of the popularizer conflict, the author points out that, in one way, Sagan asked for it, but it was also inevitable. True, "Cosmos" was huge, but Sagan's celebrity goes back even further. In 1973, he made the first of many appearances on Johnny Carson's "Tonight Show." His work as an exobiologist—one who studies, or at least looks for, life beyond Earth—raised a lot of eyebrows, and Sagan was eager to discuss his theories and findings.

Although Sagan's scientific work was tremendously significant—among many other things, he discovered the greenhouse effect on Venus, and later applied its principles to similar effects on Earth—he did most of it at an early age. His achievements were thus easier for academics to forget in the face of his later antics.

But in one episode that would prove far more troubling than the scientific community's rejection of Sagan, Sagan himself apparently betrayed the scientific community—as well as his fans and the general public who so trusted him—by inventing science to push his own political agenda: the nuclear winter theory as an argument in favor of arms control.

But Poundstone's biography goes far beyond nuclear winter and Sagan's conflicts with his colleagues. *A Life in the Cosmos* stretches to include—and appraise—Sagan's childhood in Brooklyn, his early scientific endeavors, his search for extraterrestrial life, the controversial nude drawings of humans he sent into space aboard the Voyager spacecraft, his Pulitzer Prize for *The Dragons of Eden*, his years at Cornell University, and, significantly, his often complicated relationships with his three wives and his children. He was at times self-absorbed and neglectful of his family, but most of the time he was doting, caring, and thoughtful. Anne Druyan, Sagan's third wife, had by far the most impact on him. In her, Sagan found his soul mate, and the two collaborated on many projects.

At the time Sagan died in 1996, after a long bout with bone disease, he was still a popular figure, a valued consultant to NASA Administrator Daniel Goldin, and a regular contributor—often with Druyan—to *Parade* magazine, which has a weekly readership of over 80 million. In these two collaborations, it's clear that Sagan indeed stayed true to himself—he was both a popularizer and a scientist.

—Eric Adams is an associate editor of Air & Space.

SPACE GEAR: IN PAPERBACK

U.S. Space Gear: Outfitting the Astronaut

by Lillian D. Kozlowski. Smithsonian Institution Press, 1994. 238 pp., \$19.95 (paperback).

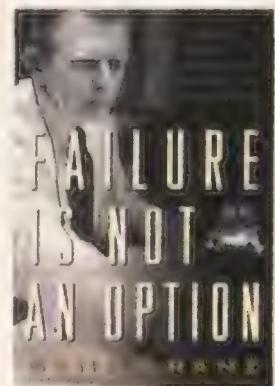


Re-released this year, this book traces, in great detail, the development of suits from those worn by Wiley Post during his high-altitude flights to the modern garb worn by shuttle astronauts.

Failure Is Not an Option

by Gene Kranz. Simon & Schuster, 2000. 415 pp., \$26.00.

Calling legendary NASA mission controller Gene Kranz a geek is a bit like calling football great Rosey Grier a sissy because he needlepoints. No one in their right mind would do such a



ON THE TUBE

Inside a Black Box

Premieres Sunday, June 18, at 8:00 p.m. on Discovery Channel.

Explores the history of using flight data recorders and cockpit voice recorders to discover the causes of air crashes.

Air Power

Premieres Wednesday, June 14, at 9:00 p.m. on The Learning Channel.

Covers the first use of laser-guided bombs in Vietnam and their effect on warfare.

Korean War: Fire & Ice

Premieres Sunday, June 25, on the History Channel.

A four-part series about the Korean War premiering on the 50th anniversary of the beginning of the war. The series examines the three-year conflict and how it affected the East and West as they faced off during the cold war.

Making of a Bloodbath (8:00 p.m.)

North Korea attacks South Korea

Triumph to Tragedy (9:00 p.m.)

General Douglas MacArthur's counteroffensive at Inchon nearly defeats the North Koreans until the Chinese enter the war.

Retreat from Hell (10:00 p.m.)

Battered U.N. forces fight their way out of a Chinese trap in the longest retreat in U.S. military history.

Bitter Standoff (11:00 p.m.)

President Truman relieves General MacArthur of command; a stalemate results in two years of fighting while a peace plan is worked out.

Lessons of a Forgotten War

Premieres Sunday, June 25, at 7:00 p.m. on the History Channel.

Examines newly declassified information about the causes of the Korean War and miscalculations made on both sides.

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REVIEWS & PREVIEWS

thing. Yet Kranz, a fighter jock who flew F-86s in Korea, was a card-carrying nerd as comfortable with a slide rule as he was at the stick of a Sabre. He represents an era when machismo turned a corner: No longer were bravery and physical skill the only requirements for earning the respect of your peers. You needed a master's in engineering as well.

Kranz brings this transition to life in his memoir *Failure Is Not an Option*, and he summarizes the transformation, which began for him and his colleagues in the early 1960s with the first manned Mercury missions, perhaps most succinctly when early on he refers to someone—without a trace of irony—as a “hotshot teletype operator.” NASA’s mission control center was, without a doubt, the birthplace of geek chic.

When Kranz arrived at Cape Canaveral in October 1960, he was there to invent a job—and do it fast. A hair-raising 90-mph ride from the airport, courtesy of astronaut Gordon Cooper, set the pace, and it never let up until Apollo 17 came home from the moon 12 years later. Kranz’s first task upon arrival, given to him by boss Chris Kraft, was to write a flight control procedures manual. He threw himself into the project, assessing faltering communication networks, byzantine computer procedures, and the hundreds of go/no-go scenarios controllers would encounter.

Much of the early work centered on unmanned test flights of the new rockets. It was in these that the newness of it all became clear to Kranz, especially after one particularly dismal launch failure, which ended with a live, fully pressurized Redstone sitting on the pad completely disconnected from mission control. The rocket was on the verge of toppling because a parachute that prematurely deployed from the escape tower was catching wind. After numerous risky solutions were tentatively proposed, the team realized that the best solution would be to simply wait. By morning, the batteries would be depleted and valves would open and release pressure. The failure ended peacefully, but others didn’t. Many times rockets blew up on the pad shortly after launch. After the initial failures, though, most of the flights were successful, and Kranz escorts readers through all the Mercury, Gemini, and Apollo missions with an admirable pace, never straying far from the focus on mission control and somehow never leaving the reader wanting more, even when recounting the struggles of Gemini rendezvous and spacewalks, the loss of the Apollo 1 crew, the first moon landing, and the

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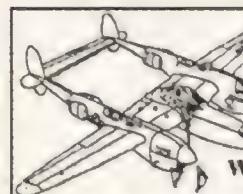
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near-tragedy of Apollo 13. He even gives readers the stories behind each of the vests—made by his wife, Marta—he wore while at the console.

But what Kranz does best is convey the atmosphere of a time and place that saw the birth of something new and spectacular. He tells of late night meetings in the local bar—Cape Canaveral was a tiny community then—to discuss the day's launch, the pressure of a looming deadline, and the impossibly complicated technology that thousands created. He revels in the camaraderie he shared with his teams and, eventually, the astronauts as successes piled up, challenges steepened, and failures, some fatal, made them work ever harder to get safely to the moon.

—Eric Adams is an associate editor of Air and Space.

W.W. I Aeroplanes: The Journal of the Early Aeroplane

Published by Leonard E. Opdycke,
15 Crescent Rd.,
Poughkeepsie, NY
12601, (914) 473-
3679. One-year
subscription:
\$30.00.



If the sheer number of serial publications devoted to the subject is any gauge, public interest in the history of flight is soaring. Recently, the newsstand where I shop displayed eight monthly or quarterly periodicals entirely devoted to aspects of aviation history. In addition, there was the usual assortment of special "one-time" magazines on subjects ranging from the career of the Avro Lancaster to

CLASSIC PLASTIC

Airfix: Celebrating 50 Years of the Greatest Plastic Kits in the World

by Arthur Ward.
HarperCollins
Publishers, 2000.
192 pp., color and
b&w photos, \$35.00
(hardbound).

A fun reminder for anyone whose fingers are still glue-sticky from building an Airfix Spitfire, Mustang, Lancaster, or Saturn V in his youth.



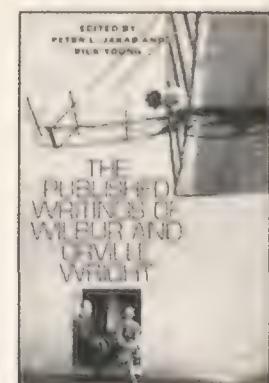
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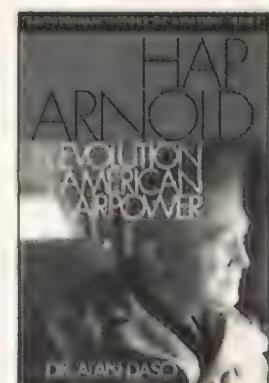
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Foreword by Richard Overy

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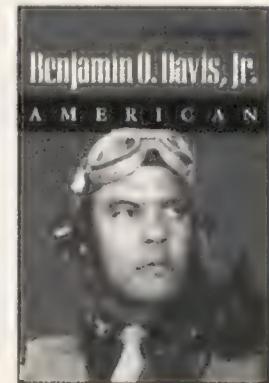
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If you're a helicopter enthusiast, you'll be happy to learn that no fewer than four rotary-wing simulations are currently on the drawing board: MicroProse's *Gunship!*, GT Interactive's *Ka-52 Team Alligator*, Novalogic's *Comanche 4*, and Empire Interactive's *Comanche vs. Hokum*. At the time of this writing, however, information was only available for the first pair of games:

Gunship! MicroProse, (800) 400-1352, www.micropsole.com, \$49.99.

During the 1980s and early 1990s, many air combat aficionados considered MicroProse to be the undisputed king of the virtual battlefield. Over the past few years, however, other companies have made great strides, particularly in the area of helicopter warfare, leaving many to wonder if MicroProse will stay on top.

Enter *Gunship!*, the third installment in its like-named series. In terms of versatility, *Gunship!* has been designed to appeal to a much wider international audience, and contains among other things flyable versions of the U.S. Army's AH-64A Apache and AH-64D Longbow, Germany's UHT-2 Tiger, Britain's Westland Apache, and Russia's sleek Mi-28N (NATO designation "Havoc").

In the single player mode, a player can fly the attack helo from the pilot seat or if he prefers, from the co-pilot/gunner's position. Whichever position he chooses, the computer will automatically handle the other crewman's functions, following a set of player-issued orders.

On the multiplayer front, MicroProse had hoped to implement a "tandem cockpit," whereby one player acts as the pilot while a second player serves as the copilot/gunner. Unfortunately, it appears the designers had to abandon this feature because of added development time. While that's disappointing, the designers saw to it that *Gunship!* could at least support up to six players in more traditional multiplayer roles.

Although the game has a more action-oriented feel than either of its predecessors, its dazzling graphics and remarkable attention to detail enable it to more than uphold its place in the *Gunship* series.

Microprose's Gunship! features simulations of the U.S. AH-64 Apache, Germany's UHT-2 Tiger (below), Britain's Westland Apache, and Russia's Mi-28N "Havoc." Simis' *Ka-52 Team Alligator* duplicates Russia's new tandem-rotor attack helo.



Ka-52 Team Alligator. GT Interactive, (800) 610-4847, www.gtinteractive.com, \$49.99.

While the U.S. Army's family of attack helicopters has been the subject of numerous simulations, the Kamov Design Bureau's Ka-52 "Alligator" (NATO designation "Hokum-B") is an untested platform, ready, at least in principle, to undergo baptism by fire. Developed by Simis, the same people who created the highly successful *Team Apache*, *Ka-52 Team Alligator* is the first attempt by a commercial developer to depict Russia's super-secret attack helicopter. *Ka-52* incorporates a new high-fidelity, 32-bit game engine offering high detailing and a wide array of terrain types. In addition, the new game engine, code named "Daedalus," can display a much wider array of animations on the battlefield—from ground scorching and scarring to bomb and artillery craters. It is even capable of rendering additive effects like rain and snow.

Despite having to work with little information on the actual helicopter, the Simis rendition is impressive. The simulated *Ka-52* exhibits the same anti-torque effects found in a coaxial-based rotor system, and places the Alligator's lethal 2A42 30-mm cannon on the starboard wing (instead of under the nose like many other helicopters). And just like the actual Alligator, the simulated *Ka-52* even includes twin "zero-zero" ejection seats to blast the simulated crewmen clear of the cockpit.

Like *Gunship!*, *Team Alligator* includes an intelligent computer-controlled crewman, although in *Alligator's* case, you'll be able to see your crewman manipulating the controls in the cockpit. *Team Alligator* also offers several modes to choose from, including independent scenarios to multi-mission campaign games set in the republics of Belarus and Tajikistan. There's even a cooperative multiplayer mode that can support up to 16 players operating in eight gunships.

Even if you're not getting tired of the NATO tank busters, give the Russian equivalent a test drive—you won't be disappointed.

—Marc Dultz is a freelance computer software reviewer.



the work of artists specializing in painting historic aviation scenes. Mind you, I did not count magazines like *Air & Space* and other general interest aerospace periodicals that may contain considerable material on the history of flight, or even the magazines targeting scale model aircraft builders and other hobbyists, which are filled with detailed articles on the history and markings of specific aircraft.

And that is only the tip of the iceberg. The magazines and journals that are most prized by the cognoscenti never appear on the newsstand shelves. Take the case of *W.W.I Aero*. While I am told that a few hobby stores stock issues, the only way to be certain of receiving each one is to subscribe. The journal is the product of World War I Aeroplanes, Inc., a tax-exempt service organization founded in 1961 by Leonard E. Opdycke, who, 39 years later, continues to edit the magazine. The organization began publication of a second periodical, *Skyways: The Journal of the Airplane, 1920-1940*, in January 1987. A fine publication, much beloved by those who treasure the aircraft of the Golden Age, it is also more traditional than its stablemate.

W.W.I Aero "...is a journal of the early aeroplane," Opdycke explained in an early issue, "offering histories, photographs, construction drawings, [information on] engines, performance data, models and lore written by experts." The experts, for the most part, are members of the organization. Other aero history periodicals, including the *Journal of the American Aviation Historical Society* and *Over the Front*, also rely on the contributions of members. Opdycke's approach is distinctive, in that it facilitates debate among his readers. As a result, issues of *W.W.I Aero* are connected to a great degree. A discussion begun in one issue is like a stone thrown into a pond, inspiring other commentators to amplify, clarify, applaud, or correct what has come before.

A typical issue may contain detailed articles on early aircraft projects, notes on the lives of early aeronautical pioneers, and step-by-step reports on building or flying replicas. Regular features include installments in an ongoing discussion of aircraft cockpits and photographs of current restoration projects. A wants and disposals section offers members an opportunity to acquire or sell the odd engine, airframe, or piece thereof. There are technical drawings of everything from propellers to entire aircraft, and reviews of everything from a

German language volume on the Fokker Dr. I through the latest plastic models of World War I aircraft.

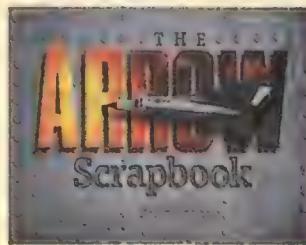
One feature of the journal deserves special comment. An issue rarely goes by without at least a few paragraphs devoted to historiography. In a nutshell, historiography is the practice of studying how history is recounted—understanding research tools, weighing evidence, constructing balanced narratives, and learning how great historians of the past practiced their craft. Opdycke draws on the *Oxford English Dictionary* to differentiate between the antiquarian ("one who investigates relics and monuments...") and the historian, who serves as an analyst, (... "esp. one who produces a work of history in the highest sense, as distinguished from the simple annalist or recorder of events..."). While praising antiquarians for uncovering the stuff of history, the editor clearly applauds the pursuit of "history in the highest sense." Over the years he has used his column as a pulpit from which to call into question the diligence of the "aviation press," broadly defined, and to encourage his own reader/contributors to do their own research. That's not what you expect to find in a publication aimed at aviation history buffs. But then, the editors of more traditional magazines are not all that interested in engaging their readers in a dialogue. *W.W.I Aero* is as interactive as a printed magazine can be. Opdycke deserves the thanks of aero historians of all stripes for almost four decades of solid information, research leads, insight, raw material, and yes, some entertainment of the best sort. Most of all, we are in his debt for providing a forum where everyone interested in the fine points of early aviation can be heard.

—Tom D. Crouch is the senior curator of the aeronautics department of the National Air and Space Museum.

THE ARROW, REVEALED

The Arrow Scrapbook

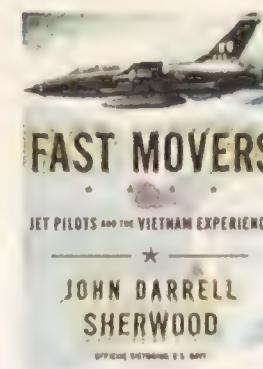
by Peter Zuuring.
Arrow Alliance, (613) 874-2838, 1999. 270 pp., b&w and color photos, \$40.00 (hardbound).



A treasure trove of diagrams, charts, and minutiae about de Havilland's famed interceptor, which was canceled in 1959. Peter Zuuring's Arrow Alliance is an organization intent on rebuilding a flyable Arrow.

Fast Movers: Jet Pilots and the Vietnam Experience

by John Darrell Sherwood. Simon and Schuster, 2000. 288 pp., \$26.00 (hardbound).



Fast Movers could have easily been another one-dimensional "There I was" book, with daring aviators retelling their best yarns, but it is far from that. True, John Darrell Sherwood, the official historian of the United States Naval Historical Center, focused on six phases of the Vietnam air war by centering the story on individual pilots—a mix of notables like Air Force Colonel Robin Olds and others unknown until now. But in the telling of each aviator's story, we see more than an aviator's bravado—rather, a whole person emerges. And in the process of getting to the action or deeds of the highlighted aviators, we meet others who were significant, but perhaps forgotten, in the events recounted.

Sherwood selected 14 aviators from more than 300 interviews. As seen through the eyes of these Air Force, Navy, and Marine Corps aviators, the air war in Vietnam was not one daring mission after another; it was a long, protracted, deadly war that saw U.S. forces lose more than 8,000 fixed-wing aircraft and helicopters. The war was characterized by frustrating politics, poor leaders, bad weather, good whiskey, dark nights, scary missions, pain, fear, introspection, and jubilation. Throughout *Fast Movers*, the narrators describe air combat in Vietnam as they saw it, without trying to be discreet or politically correct. The cast of characters included MiG killers, hotshots, POWs, and both the heroic and not-so-heroic. Sherwood brings the stories to life in a fullness not often found in such books as he recounts the acts of the men and describes the lethal machinery that made it all possible.

This is by far one of the best books on the air war in Vietnam. I would like to have seen a longer book, for Sherwood is a superb storyteller, and I'm sure he could have written more—much more—but maybe in his brevity Sherwood has written an unvarnished classic of the Vietnam air campaign.

—Lieutenant Colonel Bob Hanson (U.S. Air Force, ret.) is a career fighter pilot who flew F-4 Phantoms in Vietnam. He wrote "Counterpunch" for the Aug./Sept. 1998 issue.



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Aircraft Owners and Pilots Association Fly-In and Open House. AOPA Headquarters, Frederick Municipal Airport, Frederick, MD, (301) 695-2162.

June 10 & 11

Aurora AirExpo Fly-In. Aurora Municipal Airport, Sugar Grove, IL, (630) 466-4579.

June 11

Spencer Flagfest Airshow and Flight Breakfast. Spencer Municipal Airport, Spencer, IA, (712) 264-3107.

June 15-18

Waco Club Fly-In. Creve Coeur Airport, St. Louis, MO, (616) 624-6490.

June 17 & 18

Deke Slayton Airfest. LaCrosse, WI, (608) 779-9994.

June 24

San Diego Aerospace Museum Aviation Collectible Swap Meet. Gillespie Field Annex, El Cajon, CA, (619) 234-8291.

Talisman Field Picnic and Fly-In. Talisman Farm, Grasonville, MD, (410) 827-7154.

June 24 & 25

Rocky Mountain EAA Regional Fly-In. Vance Brand Airport, Longmont, CO, (303) 442-5002.

June 30-July 4

Reunion: Vietnam Helicopter Pilots Association. Renaissance Hotel, Washington, DC, (800) 505-VHPA.

July 8 & 9

1941 Aircraft Group Fly-In. Geneseo Airport, NY, (716) 243-2100.

"Heros and Legends" Air Festival. Cape Girardeau Regional Airport, Cape Girardeau, MO, (573) 334-6230.

"Wings of Victory" Airshow. Fairfield County Airport, OH, (740) 653-8593.

July 15

Fly-In Whitefish Boil. Sponsored by the Washington Island Lions Club. Washington Island Airport, WI, (920) 847-2770.

July 19-22

Airliners International Collectibles Show. Camelback Inn, Scottsdale, AZ, (602) 564-1666.

July 21-28

"Gathering of Eagles" Airshow. Lost Nation Airport, Willoughby, OH, (440) 943-0084.

July 22 & 23

Air and Trade Show. Dayton International Airport, OH, (937) 898-5901.

Royal International Air Tattoo and Airshow. Royal Air Force Cottesmore, Rutland, England, phone 01285 713300, ext. 3341.

July 28-30

Reunion: VR-52, -62 Detroit. Port Clinton, OH, (727) 862-6343.

Cover. Matthew Frey is the art director for Wood Ronsaville Harlin, Inc., an illustration and design firm in Annapolis, Maryland. He is the co-illustrator of *One Universe: At Home in the Cosmos* (John Henry Press, 2000), the companion book to the American Museum of Natural History's new Rose Center for Earth and Space in New York City.

Deep-Sea Fishing. Curt Newport has participated in numerous underwater operations such as the salvage of Air India Flight 182, the space shuttle *Challenger*, and TWA Flight 800. He is currently writing a book about the *Liberty Bell 7* recovery.

Manhattan Transfer. Lester A. Reingold is a frequent contributor. For this article, he found himself perched on a narrow, open walkway on the Empire State Building, trying not to think about King Kong.

Birds Do It Better. Adele Conover writes frequently for *Smithsonian* about wildlife.

The Truth Is Down Here. Bijal Trivedi is a staff writer for the Genome News Network, an online publication that covers genetics and genomics. She harbors a desire to visit the moon or Mars, or even just to orbit Earth for a few days.

The Forgotten Fighter. Warren E. Thompson is the author of 12 books on military aviation, most recently *Bandits Over Baghdad*, an account of the F-117 stealth fighter in Desert Storm, to be published soon by Specialty Press.

The Heroes. John Sotham is an associate editor at *Air & Space/Smithsonian*.

Breakout from Chosin. Joe Sugarman is a Baltimore-based freelance writer.

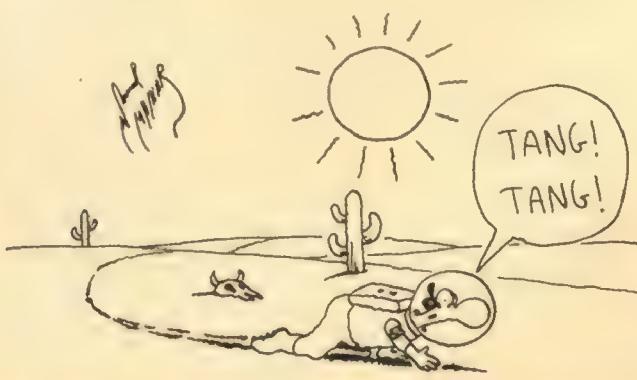
The Aircraft. Veteran illustrator Harry Whitver is based in Nashville, Tennessee.

Light and Magic. Eric Adams is an associate editor at *Air & Space*.

Learn to Fly. A pilot since 1976, Scott M. Spangler was the editor of *Flight Training* magazine for its first 10 years. In 1999 he became editor-in-chief of publications at the Experimental Aircraft Association.

Water, Water Everywhere... Stam Predrag is a veteran correspondent covering Africa south of the Sahara for several American, Canadian, and European newspapers and magazines.

Bomb Squad. James Schultz is a freelance journalist who writes on science and technology from his home in Williamsburg, Virginia. He is the co-creator and editor of *Quest*, a magazine that covers research innovations and scientific breakthroughs (www.odu.edu/~instadv/quest).

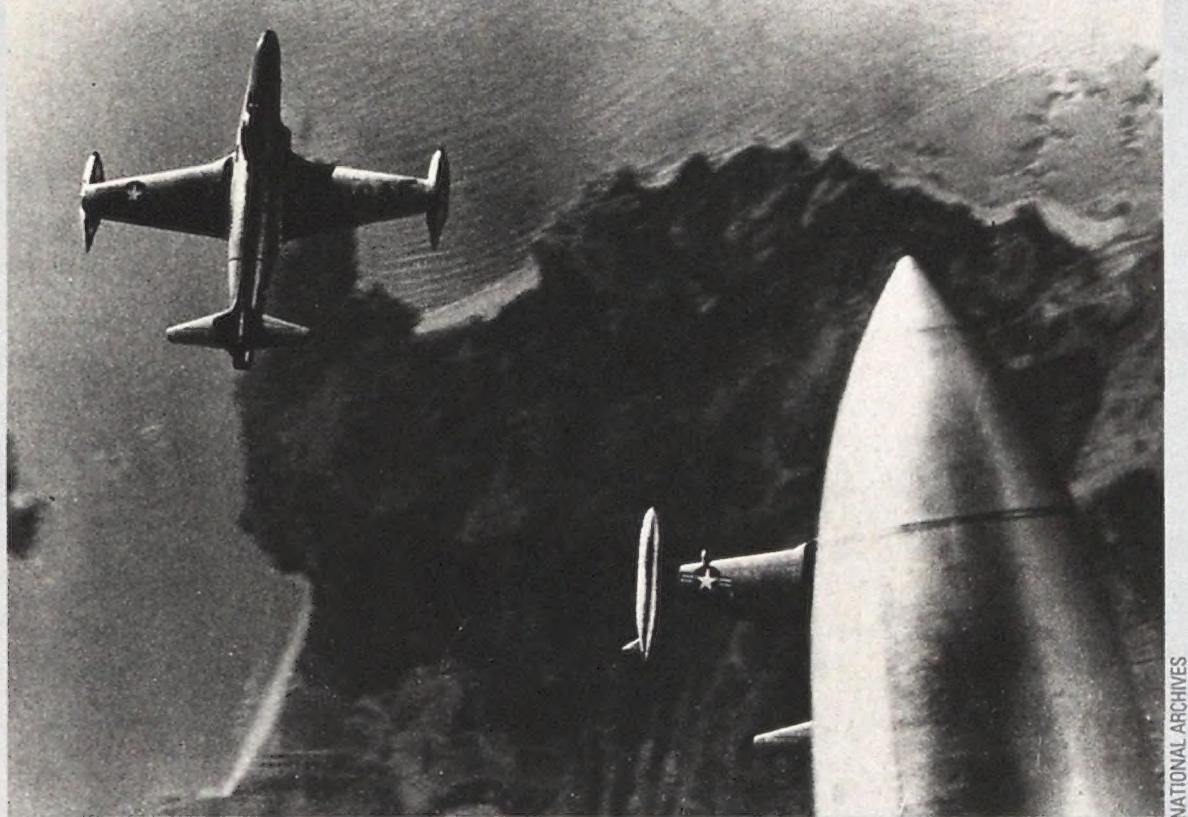


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NATIONAL ARCHIVES

FORECAST

In the Wings...

Tommy Gold's Camera

You have never seen the photographs that will appear with this story, even though they are the most detailed pictures ever made of the moon's surface. So why are they lying in a forgotten box in an office at Cornell University?

Through the Eyes of Ben Ross

The photographer who showed us the airplane as it had never been seen before.

Special Report: The Age-Old Question

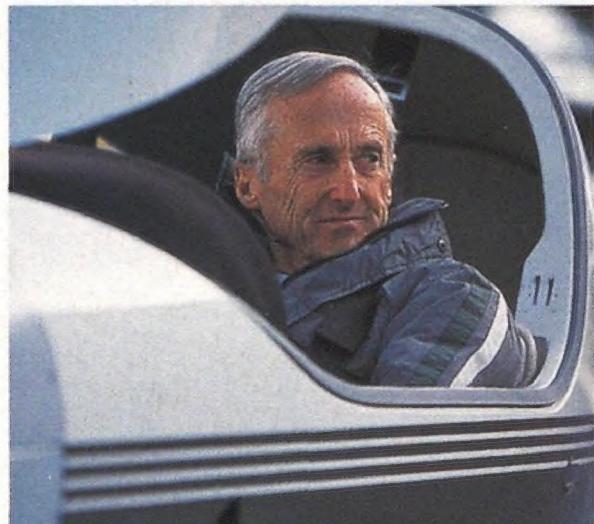
The FAA has ruled that airline pilots must retire at 60. Is it time to retire the rule?

Test Pilots Too

Somebody has to wring out the Cessnas and Mooneys to see what those babies can do.

The Return of Darryl Greenamyer

Reno's racing legend is back, this time in a new event: the Sport Class. Ever a gambling man, Greenamyer (below) is betting that air racing itself will be reborn.



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The Record Man

Nobody keeps the staff of the NAA busier than Steve Fossett (below), simply because few living persons have set as many records in aeronautics as Fossett has. Luckily for the NAA, other bodies maintain the records for events like the Iditarod dog team race in Alaska, the Ironman Triathlon, and the English Channel swim. Fossett has finished in all of those, too.

Flying everything from balloons to business jets, Fossett has set marks for time, distance, speed, and altitude. Probably his most memorable record attempt was a solo balloon flight in which he set out from Argentina to circle the globe. With the whole world watching, the flight ended when Fossett had to ditch in the Coral Sea short of his goal, but the attempt still stands as the long-distance record for a solo flight in any form of aircraft.

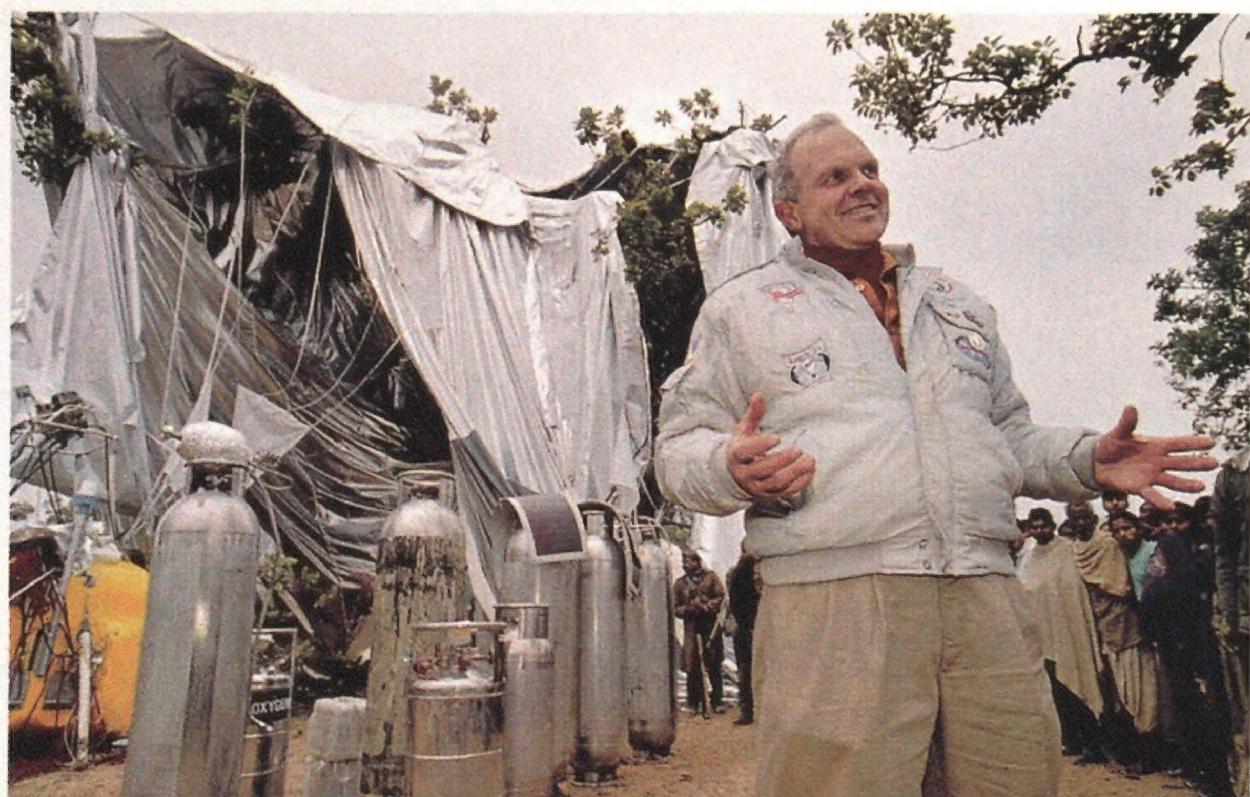
Most recently, Fossett has been setting records in his new Cessna Citation X. Last February, Fossett and two copilots circled the globe in the speedy twin jet, landing after only 41 hours, 13 minutes. That time, combined with an average speed of 559 mph,

established a world record for medium airplanes and knocked more than six hours off the previous mark.

Fossett says that what connects all of his activities is his fascination with technology. "Our sailboat is at the cutting edge, with our balloon we had to find new ways to get more endurance, and the Citation X is also at the leading edge [in its category]," he says.

His successes and attempts at records began in 1991, he says, when he started to think about what he wanted to do in adventure sports. His first two goals: "To sail the Atlantic single-handed, and to go around the world in a balloon," he says. "As I got into those sports I realized that it was possible to go a lot farther and faster than anyone had before," says Fossett. "[Technology] afforded me a tremendous opportunity to set records."

Beginning in this issue, Moments & Milestones, produced in association with the National Aeronautic Association, will summarize events recorded in the NAA archives.



AP PHOTO/JOHN MOORE

MILESTONES

Awards

On March 16 in San Diego, California, Russell W. Watson of Wichita, Kansas, was awarded the **1999 Frank G. Brewer Trophy for Aviation Education**. A guidebook co-authored by Watson is credited with a key role in launching aviation courses in at least 350 of the nation's community colleges.

In recognition of the top aeronautical achievement in the United States during 1999, the **Collier Trophy** has been awarded to the Boeing company, the Hornet Industry Team, and the U.S. Navy for "designing, manufacturing, testing, and introducing into service the F/A-18E/F multi-mission strike fighter aircraft, the most capable and survivable carrier-based combat aircraft." The Collier Trophy, considered the most prestigious honor in U.S. aviation, was presented to the winning team on May 3.

Records

November 1999: R. W. "Buzz" Kaplan and Jim Hanson in a float-equipped Cessna 208 Caravan across the Drake Passage to Antarctica, 167 mph and 172 mph for two legs of the trip. • December 1999: James Gross, Anthony Adams, and Walter Cappelli in an American Airlines Boeing 777-200 from Dallas, Texas, to Osaka, Japan, 516 mph. • February 2000: Arlen Rens and crew in a C-130J Hercules from Pope Air Force Base, North Carolina, to Cambridge, England, 410 mph.

Call for Nominations

Nominations are due on June 30 for the Elder Statesmen of Aviation award honoring significant contributions to aeronautics, the Catherine and Marjorie Stinson Award for enduring contribution by a living woman, and the Henderson Achievement award for a living individual or group making a significant and lasting contribution to promoting or advancing aviation or space activity. For additional information on awards or records, visit the NAA's Web site at: www.naa-usa.org.

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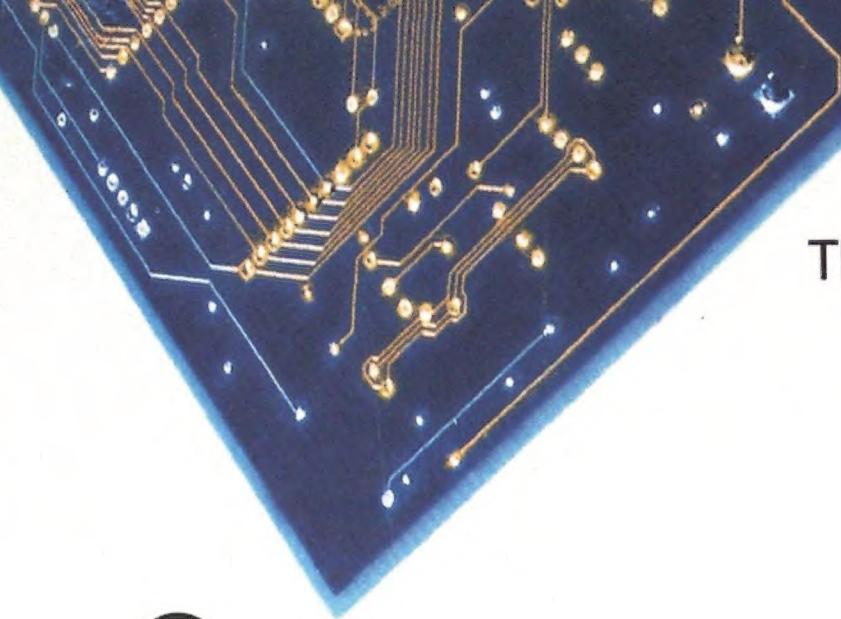
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